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# EXPERIMENTS

# ON

# HOT WATER SYSTEMS,

BY

## A. SAYERS,

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WITH PREFATORY STATEMENT BY

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# PREFATORY STATEMENT.

THE experiments described in this book were carried out by Mr. A. Sayers in the Plumbing Workshop of the Municipal Technical Institute, Belfast, during the years 1902, 1903, and 1904.

I was fortunate in having the opportunity of watching the progress and development of the experiments, and I take it that it is for that reason Mr. Sayers has paid me the compliment of asking me to write an introductory statement to his work.

It is interesting to note the steps by which these experiments developed. Shortly after the apparatus described in the book had been erected, a discussion arose as to the rate at which the heated water travelled through the pipes. This led to a proposal to insert thermometers at different points in the pipe system, and to have these read at regular periods during the progress of an experiment. This was done, and a series of temperature readings thus obtained.

How to display the whole of these readings, in such a manner as to exhibit their relation to one another, was the next question that arose, and the consideration of this led to the adoption of the graphical method so freely and so helpfully used throughout the book.

As a constant and very interested observer of the experiments during their progress, I can bear testimony to the care and pains taken to secure complete accuracy in the tabulated data. Mr. Sayers approached the experiments with a genuine enthusiasm, and dealt with the problems that arose in a true spirit of scientific investigation. The practical knowledge which he possesses ensured the practical aspect of the problems he was dealing with being always kept well in view: as a consequence, the results herein recorded should have an especial value to practical men.

The book contains within itself evidence of the thoroughness with which the researches were carried out, and makes clear that the results obtained form an entirely original contribution to the subject of hot water circulation. Those more competent to judge of the practical aspect of the question than I am, have stated that the book throws much light upon many hot water circulation problems hitherto very little understood.

I do not doubt that as the experiments herein described become better known to plumbers, the methods of experimental research which they exemplify will be availed of to a far greater extent than has been the case up to the present.

Whilst Mr. Sayers spared himself no trouble in conducting the experiments, it should be mentioned that he was very ably assisted by the plumbing students attending the Municipal Technical Institute. It was a source of great satisfaction to see the thoroughly intelligent interest which these young men took in the experiments, and to observe the useful aid they rendered to their teacher.

As an evidence of the importance attached to the researches described in this book, it is worthy of mention that the Library and Technical Instruction Committee of Belfast have awarded to Mr. Sayers the Dufferin Bronze Medal, a reward given only for original investigation.

FRAS. C. FORTH,
*Principal,*
*Municipal Technical Institute, Belfast.*

FEBRUARY, 1906.

# CONTENTS.

Page.

PREFATORY STATEMENT ... ... ... ... iii.

INTRODUCTION—Description of Apparatus employed; method of recording results ... ... ... ... 1

EXPERIMENT III:—Cylinder system; insufficient boiler and heating power; detailed explanation of graphical illustrations ... ... ... ... 11

EXPERIMENT IV.:—Cylinder system; improved boiler and heating power ... ... ... ... 16

EXPERIMENT V.:—Cylinder system; draw-off table of boiling points of water ... ... ... ... 19

EXPERIMENT VI.:—The effect of a bye-pass on cylinder system; direction of flow when tap is open ... 26

EXPERIMENT VIA.:—Confirmatory experiment ... ... 32

EXPERIMENT VII.:—Cylinder system; the advantage of connecting flow to top of cylinder ... ... 37

EXPERIMENT XII.: Flow connected to botton of cylinder ... 42

EXPERIMENT XIII.:—The evil of connecting draw-off branches to primary flow-pipe... ... ... 47

EXPERIMENT XV.:—The evil of connecting draw-off branches to primary flow-pipe ... ... ... 52

EXPERIMENT XVII.:—The evil of connecting draw-off branches to primary flow-pipe ... ... 57

EXPERIMENT XIX.:—Treatment of the cold supply-pipe to hot-water systems ... ... ... ... 61

EXPERIMENT XX.:—Treatment of the cold supply-pipe to hot-water systems ... ... ... ... 65

EXPERIMENT XXII.:—The bad effects of connecting the cold supply-pipe direct to the boiler ... ... 69

EXPERIMENT XXIII.:—The bad effects of connecting the cold supply-pipe direct to the boiler ... ... 73

ILLUSTRATION:—Showing the best method of making connection to the cylinder ... ... ... 77

ILLUSTRATION:—Showing unsightly circulating pipes crossing a window ... ... ... ... 78

ILLUSTRATION:—Showing how crossing a window with pipes may be avoided ... ... ... ... 80

TABLE:—Giving average temperature of water drawn off ... 81

EXPERIMENT VIII.:—Dip in return-pipe ... ... 83

EXPERIMENT IX.:—Dip in return and flow-pipe ... ... 87

EXPERIMENT X.:—Air lock in circulating pipes; its causes ... 91

EXPERIMENT XI.:—Air lock in circulating pipes, and how to prevent it ... ... ... ... 95

ILLUSTRATION:—Hot water apparatus in glass to demonstrate air lock ... ... ... ... 99

EXPERIMENT XXI:—Expansion of water, volume of air liberated when water is heated ... ... 101

EXPERIMENTS II. & III.—Heating below level of boiler dip in pipe; ebb and flow circulation ... ... 105

ILLUSTRATION:—Showing defects in heating system ... 111

ILLUSTRATION:—Showing how defects may be remedied ... 112

SECONDARY CIRCULATION.

EXPERIMENT I.:—Secondary circulation; the evil of returning cold water into the top of the cylinder ... 113

EXPERIMENT II.:—Secondary circulation; direction of flow to a branch pipe during draw off ... ... 118

EXPERIMENT III.:—The advantages of reducing the secondary return pipe and returning it into the bottom of the cylinder or boiler ... ... ... 122

TABLE:—Giving average temperature of the water drawn off... 125

## CYLINDER AND TANK SYSTEM.

EXPERIMENTS I. & II. :— Insufficient boiler and heating power ; fall in temperature after heat was applied ... 126

ILLUSTRATION :—Showing a defective cylinder and tank system ... ... ... ... 131

EXPERIMENT III. :—Cylinder and tank system ; heats well but does not yield hot water ... ... ... 134

EXPERIMENT IV. :—Cylinder and tank system heats badly ; direction of flow when drawing off ... ... 135

EXPERIMENT V. :—Cylinder and tank system; an improved method ; heat evenly distributed ; defects of connecting secondary return to boiler ... ... 138

CONCLUSION ... ... ... ... ... 142

## APPENDIX.

HEATING SMALL VILLA FROM KITCHEN RANGE :—Methods of ventilation ; temperature of living rooms ; coal consumption ; open fires; small rooms ; unhealthy homes ; effects of dampness and how to prevent it ... 149

**Experiment** XXII.:—The bad effects of connecting the cold supply-pipe direct to the boiler ... ... 69

**Experiment** XXIII.:—The bad effects of connecting the cold supply-pipe direct to the boiler ... ... 73

**Illustration**:—Showing the best method of making connection to the cylinder ... ... ... 77

**Illustration**:—Showing unsightly circulating pipes crossing a window ... ... ... ... 78

**Illustration**:—Showing how crossing a window with pipes may be avoided ... ... ... ... 80

**Table**:—Giving average temperature of water drawn off ... 81

**Experiment** VIII.:—Dip in return-pipe ... ... 83

**Experiment** IX.:—Dip in return and flow-pipe ... ... 87

**Experiment** X.:—Air lock in circulating pipes; its causes ... 91

**Experiment** XI.:—Air lock in circulating pipes, and how to prevent it ... ... ... ... 95

**Illustration**:—Hot water apparatus in glass to demonstrate air lock ... ... ... ... 99

**Experiment** XXI:—Expansion of water, volume of air liberated when water is heated ... ... 101

**Experiments** II. & III.—Heating below level of boiler dip in pipe; ebb and flow circulation ... ... 105

**Illustration**:—Showing defects in heating system ... 111

**Illustration**:—Showing how defects may be remedied ... 112

## SECONDARY CIRCULATION.

**Experiment** I.:—Secondary circulation; the evil of returning cold water into the top of the cylinder ... 113

**Experiment** II.:—Secondary circulation; direction of flow to a branch pipe during draw off ... ... 118

**Experiment** III.:—The advantages of reducing the secondary return pipe and returning it into the bottom of the cylinder or boiler ... ... ... 122

**Table**:—Giving average temperature of the water drawn off... 125

## CYLINDER AND TANK SYSTEM.

EXPERIMENTS I. & II. :— Insufficient boiler and heating power ; fall in temperature after heat was applied ... 126

ILLUSTRATION :—Showing a defective cylinder and tank system ... ... ... ... 131

EXPERIMENT III. :—Cylinder and tank system ; heats well but does not yield hot water ... ... ... 134

EXPERIMENT IV. :—Cylinder and tank system heats badly ; direction of flow when drawing off ... ... 135

EXPERIMENT V. :—Cylinder and tank system; an improved method ; heat evenly distributed ; defects of connecting secondary return to boiler ... ... 138

CONCLUSION ... ... ... ... ... 142

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# EXPERIMENTS ON HOT WATER SYSTEMS.

## INTRODUCTION.

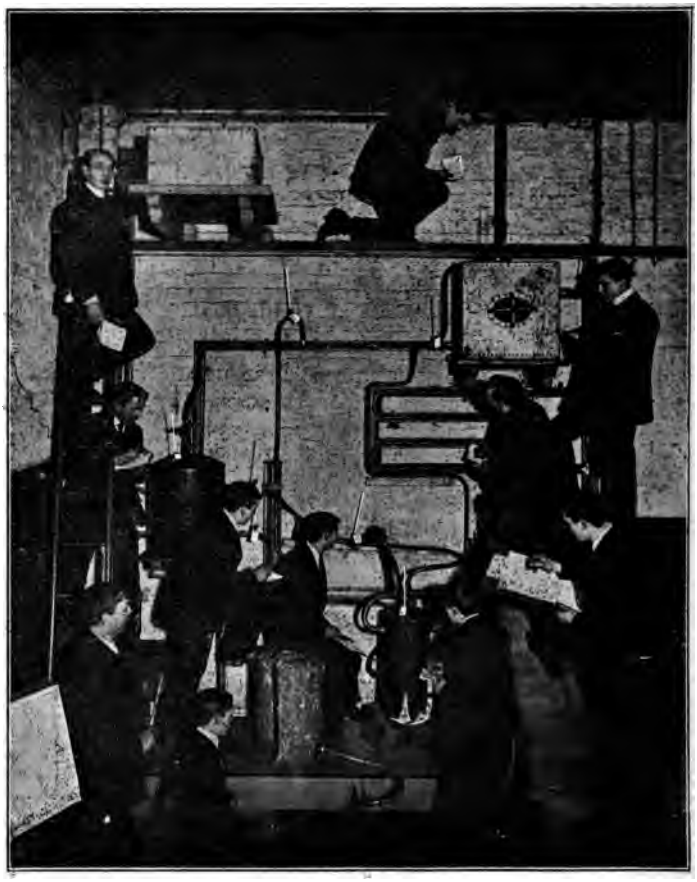
So much has already been said on the subject of hot water supply that to dwell upon the question further might appear to be an attempt to add to an already full vessel. Although the subject is not by any means threadbare, it is not my intention in these notes to add to the existing store, but rather to crystallise a few simple, yet important, facts brought to the surface by the results of experiments on systems of domestic hot water supply conducted by members of my classes at the Municipal Technical Institute, Belfast.

Experience with the trade in the workshop, and also in connection with Technical School classes, forced the fact upon me that in the matter of hot water circulation—as well, indeed, as in conjunction with other branches of the trade—a connecting link was wanting to bridge over the chasm which appears to exist between the practical man and what the plumber is pleased to call "book knowledge."

In casting around for some means whereby this want might be supplied, it occurred to me that the difficulty would be best met by having a system of hot water apparatus fitted up in the plumber's shop in our local Technical Institute, and so to place within reach of the young plumbers attending the classes a ready means of experimenting and making themselves, not alone practically, but also scientifically, acquainted with the different systems to be met with in every day practice.

The matter was laid before the Principal of the Institute, with the result that in a short time the necessary parts consisting of cistern, tank, cylinder and boiler were provided, and the work of fitting up the apparatus by members of the class put in hand. This was done during the latter period of the Session 1902-1903.

The apparatus is in every way full-sized, and the information gained by the results of numerous experiments conducted will be most useful to the students and the trade generally. When any



PLUMBING STUDENTS CONDUCTING EXPERIMENTS AT THE MUNICIPAL TECHNICAL INSTITUTE, BELFAST.

member of the class has some doubt as regards the best method of fitting up a system he may be working at, or the remedy for a defective system, the problem is made the subject of experiment at the next class meeting.

The method of conducting the experiments can be best illustrated by a photograph of some members of the class engaged in an experiment on the cylinder and tank system. The position of the various cisterns, cylinder and boiler will be seen at a glance. The cold store cistern is to the left; the hot store cistern to the right; the boiler (heated by a H.P. gas stove) below the hot store cistern. As will be seen the cylinder is immediately below the cold store cistern. It will be noticed that thermometers are fitted at different points on the system, the method of connecting these being explained later on. A number of the students in the photograph are engaged taking the readings of the thermometers. One is keeping a note of the time, another recording the readings, and a third measuring the water drawn off by means of a graduated cylinder, which will be seen opposite the student who is kneeling.

A detailed illustration of the sizes, capacity and relative positions of the various fittings is shown by Fig 1. The cold store cistern is fixed 12 ft. above the boiler. This 12 ft. head of water exerts a pressure of 5 lbs. per square inch on the boiler. The cylinder is directly below the cold store cistern and 3 ft. 9 in. above the boiler. The hot store tank is to the right of the cylinder, and 3 ft. below the cold store cistern. The position of the boiler will be noticed on referring to the drawing or photograph.

The size of the cold store cistern, as figured on the illustration, is 2 ft. by 2 ft. by 1 ft. 3 in., and contains twenty five gallons. The hot store tank measures 2 ft. by 2 ft. by 1 ft. 3 in., and holds thirty-one gallons. The cylinder, measuring 2 ft. by 1 ft. 6 in. diameter, has a capacity of twenty-two gallons, and the little block boiler is 12 in. by 8 in. by 5 in., and its capacity may be taken as one and a half gallons. The total capacity when the system is full is seventy-nine gallons, and to this must be added the water contained in the different pipes.

It is well to note the distance the different cisterns are apart, and if my readers will keep in their minds the size of the various fittings and the distances apart, the extent of the different systems experimented with will be more readily understood.

The size of pipes used in the experiments was ¾ in. (lead), and the runs will be given with the result of each experiment.

I will at this stage give the names of the different pipes. I feel that this is a necessary precaution, for even amongst plumbers certain terms, as, *e.g.*, "return" and "flow," are often applied in contradictory senses. Fig. 2 is a line diagram showing the different runs of pipes employed in domestic hot water supply.

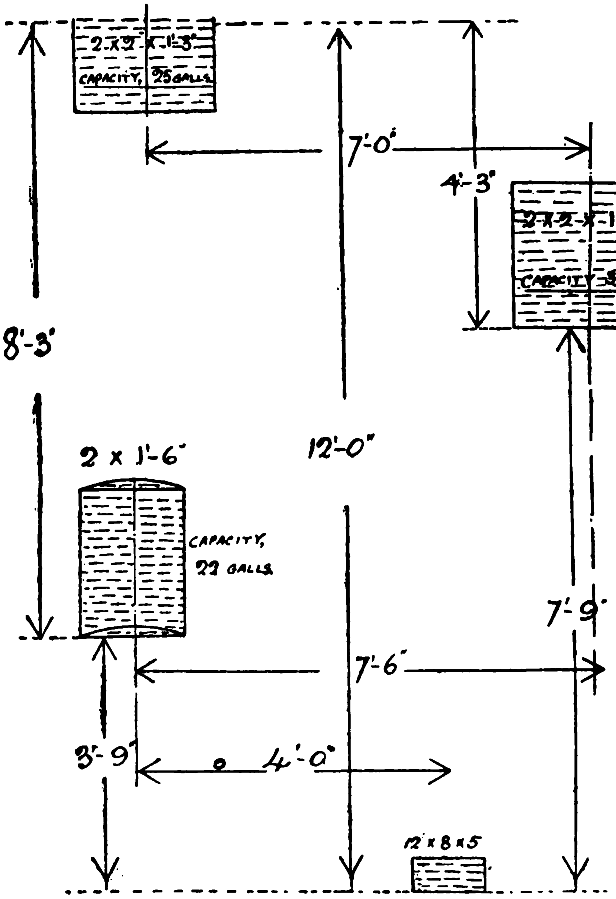

2 x 2 x 1'-3"
CAPACITY, 25 GALLS
7'-0"
4'-3"
2 x 2 x 1'-3"
CAPACITY 31 GALLS
8'-3"
2 x 1'-6"
12'-0"
CAPACITY, 22 GALLS
7'-9"
7'-6"
3'-9"
4'-0"
12 x 8 x 5

FIG. I.

The cold store cistern is supplied by a pipe from the main in street, called the rising main; the pipe between the cold store cistern and the cylinder is known as the cold supply. The pipe taken from the bottom of the cylinder and connected to the bottom of the boiler is known as the return pipe, or cold circulating pipe; and the pipe from the top of the boiler and connected to the cylinder somewhere above the return pipe is known as the flow pipe, or hot circulating pipe. Thus, when we use the term "flow" we mean that the water flows from the boiler to the cylinder, and when we use the term "return" we refer to the water returning from the cylinder to the boiler.

The pipe from the extreme top of the cylinder, when carried direct through the roof, is known as the "expansion pipe," but when connected to a hot store tank, is known as the "secondary flow pipe;" and the pipe from the bottom of the hot store tank and connected to the boiler or the cylinder, as the case may be, is known as the "secondary return pipe." Pipes employed for draw-offs are known as "branch pipes."

Having mastered the names of the various pipes the reader will be in a position to follow the experiments without the risk of misunderstanding any of the terms that may be employed.

The first system experimented with was what is known as the cylinder system, which, as most of my readers will know, consists of a cold store cistern, a cylinder and a boiler connected by cold supply, return, and flow pipes; the boiler in this case being the little block boiler, the dimensions of which I have just given. Heat was supplied by a 4 in. H.P. gas stove. In a short time after heat was applied the flow pipe commenced to heat while the return remained cold. This state of affairs continued for some time until the water in the cylinder become moderately warm, when the return pipe commenced to heat also. At this stage we had no means of testing the rise of temperature except by laying on the hand, which served our purpose for the time being, the system presenting a ready means of explaining to the students the principle of hot water circulation.

The next system experimented with was the cylinder and tank system, but the little block boiler was found insufficient to heat the cylinder and tank.

The method of laying on the hand as an indicator of rise of temperature was also unsatisfactory, and it was evident that if reliable results were to be arrived at some more scientific method must be adopted. It was decided to fit thermometers on the system, at different points, by means of stuffing-boxes and glands. These simple contrivances are on the same principle as the stuffing-box of a screw-down tap, as shown in Fig. 2 A. The fitting is made water-tight by a soft packing washer, and when it is necessary to remove a thermometer, the thermometer and soft packing washer is replaced by a solid leather washer, and the

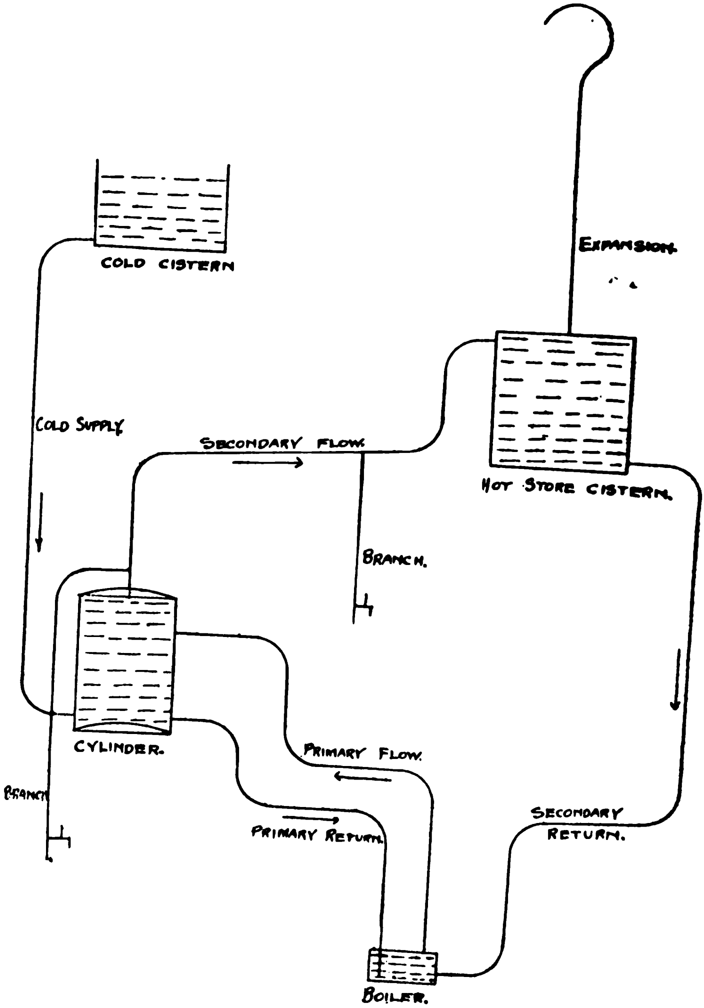

EXPANSION.
COLD CISTERN
COLD SUPPLY
SECONDARY FLOW
HOT STORE CISTERN.
BRANCH.
CYLINDER.
PRIMARY FLOW.
BRANCH
SECONDARY RETURN.
PRIMARY RETURN.
BOILER.

FIG. 2.

stuffing nut screwed up. These fittings, which somewhat resemble the tail-piece of a union coupling, are connected to the pipes by soldered joints, care being taken to in no way interfere with the free flow of water.

A substitute for the block boiler was found in an old galvanised iron steam jacket, formerly used in a restaurant for cooking purposes. This old steam jacket or boiler was inverted over a gas stove, small vents having been provided for the products of combustion. The holes in this boiler being only $\frac{1}{2}$ in., the $\frac{3}{4}$ in. pipes had to be connected by means of $\frac{1}{2}$ in. couplings, which no doubt considerably affected the flow and rendered the results to an extent unreliable.

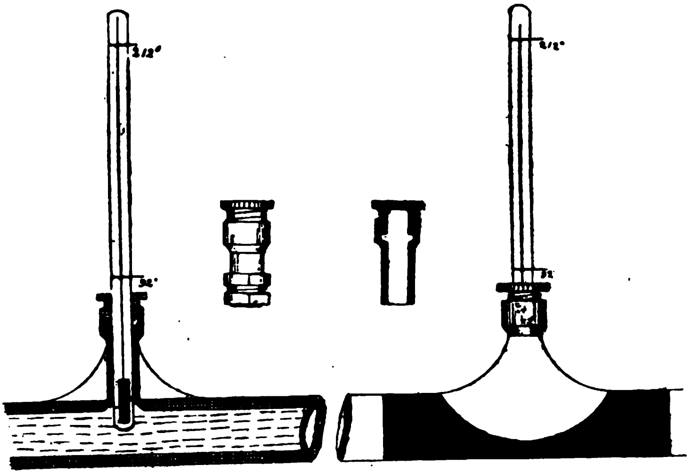


FIG. 2 A.

The experience gained by the working of the steam jacket boiler led to a copper tubular boiler being made by a number of the senior students, the copper used being 20 B.G., and the tubes 16 B.G.

The three boilers are shown in Fig. 3; the little block boiler on the left, the steam jacket boiler in the centre, and the tubular boiler to the right of the drawing.

The tubular boiler, as will be seen, is somewhat on the geyser principle. Two inverted cylinders, the diameter of the inner being 8 in., and the diameter of the outer being $10\frac{1}{2}$ in., give a waterway of $1\frac{1}{4}$ in. all round the boiler. Ten $\frac{3}{4}$ in. tubes are fitted in the inner cylinder, made watertight by two small collars and soft soldered on the inside face. Thus 7 ft. of $\frac{3}{4}$ in. tube is exposed, which in itself presents a good heating surface. The boiler is 24 in. high

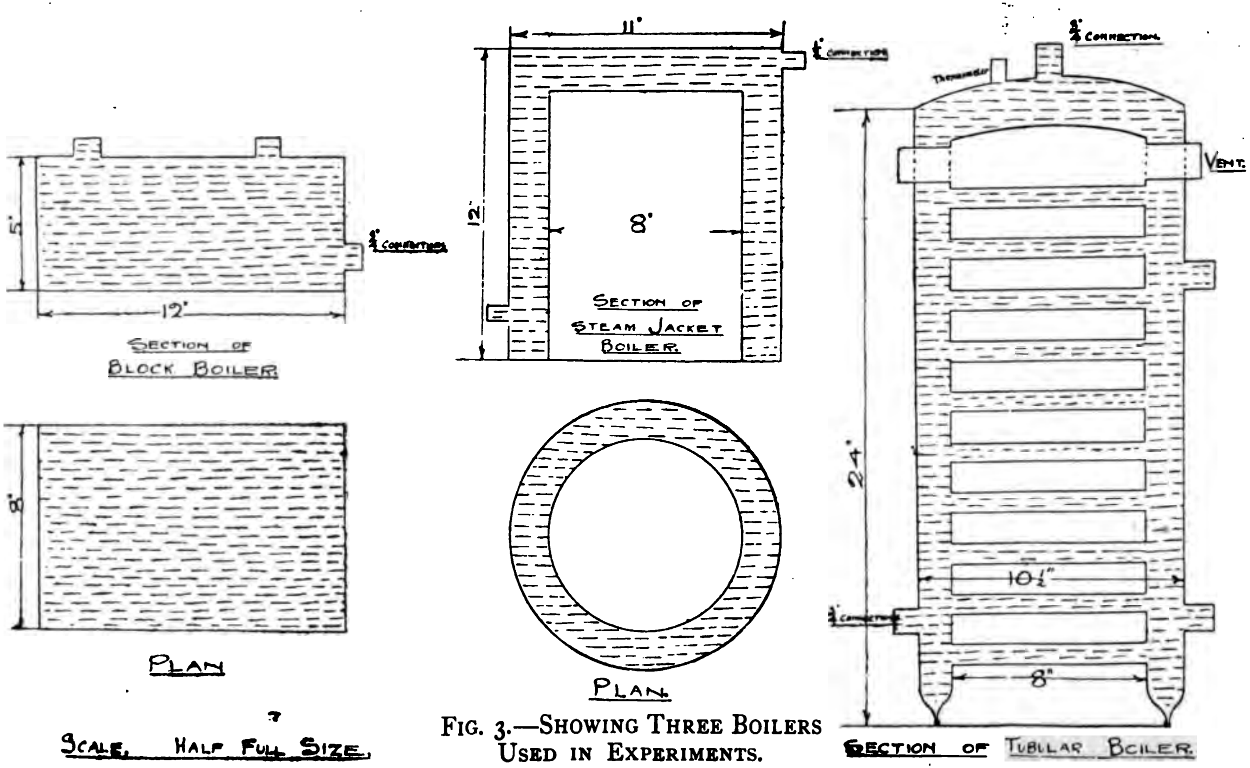


FIG. 3.—SHOWING THREE BOILERS USED IN EXPERIMENTS.

over all, the inner cylinder being 23 in. by 8 in. A heating surface of about 5½ sq. ft. is exposed to the flame, as compared with 2½ sq. ft. in the steam jacket boiler, and a little over ½ sq. ft. in the case of the block boiler.

The seams of the tubular boiler were tinned, rivetted and hard sweated, the workmanship being very creditable to those lads who were engaged in making it. To take in hand the making of a tubular boiler by a few apprentice plumbers was a bit of a venture, but the way they went about the job showed how interested they were, and inspired confidence.

Two vents were taken out of the side of the inner cylinder near the top, to carry away the fumes, provision being made for connecting the pipes to the boiler by four ¾ in. plates rivetted and hard sweated on the inside face. A thermometer fitting is also fixed on the top of the boiler, so that a thermometer may be used for taking the temperature of the water leaving the boiler. If this boiler had been made by a coppersmith the seams and connections would no doubt have been brazed. Plumbers as a rule are not versed in the art of brazing, so the seams had to be rivetted and sweated.

In these experiments, the readings of the thermometers being a complication of figures and very difficult to understand, it was decided to plot the results graphically on what is commonly known as squared paper. A little time spent in explaining this method of recording the results will enable the reader to better understand the diagrams with which these articles will be illustrated.

For the benefit of the uninitiated and those unaccustomed to diagrams, I will give the result of a miniature experiment conducted specially for the purpose, and shown on Fig. 4. The rough drawing to the left represents a glass flask containing water and fitted with a thermometer. The temperature of the water at the commencement of the experiment was noted; heat was applied very slowly by an ordinary gas stove, and the temperature of the water was taken every five minutes and duly recorded. At the commencement of the experiment the water was at a temperature of 60 degrees. At the end of five minutes the temperature was 65 degrees. At the end of ten minutes a temperature of 70 degrees was recorded by the thermometer; and so on as tabulated below:—

| | | | | | |
|---|---|---|---|---|---|
| Temperature of water at commencement of experiment | | | | | 60 deg. |
| Temperature of water at the end of | | | 5 | minutes | - 65 „ |
| Do. | do. | do. | 10 | „ | - 70 „ |
| Do. | do. | do. | 15 | „ | - 75 „ |
| Do. | do. | do. | 20 | „ | - 79 „ |

On referring to the diagram to the right of Fig. 4, the method of plotting this simple result graphically will be noticed. The paper is divided into 1-5ths of inches. Along the first horizontal line are figured minutes. In the present case each line represents 1 minute; hence, 1 inch represents 5 minutes; 2 inches, 10 minutes; 3 inches, 15 minutes; and 4 inches, 20 minutes. Along the first vertical line the degrees are figured. Each line represents 1 degree; thus 1 inch represents 5 degs.; 2 inches, 10 degs., and so on. It will therefore be seen that the vertical lines represent minutes and the horizontal lines represent degrees. The temperature of the water at the commencement of the experiment being 60 degrees, the line which is to represent the rise in temperature starts from the point figured 60 on the first vertical line. At the end of five minutes the temperature as tabulated was 65 degrees, and, as will be seen, a line drawn from the point already noted to the point where the line figured 5 minutes crosses the line figured 65 degrees on the temperature scale, represents the rise of temperature during the first 5 minutes of the experiment. At the end of 10 minutes the thermometer stood at 70 degrees. The line already studied is continued till it reaches the point where the 10 minutes line crosses the 70 degrees line, which represents the travel of the thermometer during the second five minutes. At the end of fifteen minutes a temperature of 75 degrees was reached. The point where the line representing 15 minutes on the time scale crosses the line representing 75 degrees on the temperature scale, is joined with the line already drawn, and at this stage we have a line representing the rise of temperature during the first 15 minutes. The fourth and last reading showed a temperature of 79 degrees; therefore the line already drawn is produced until it intersects the

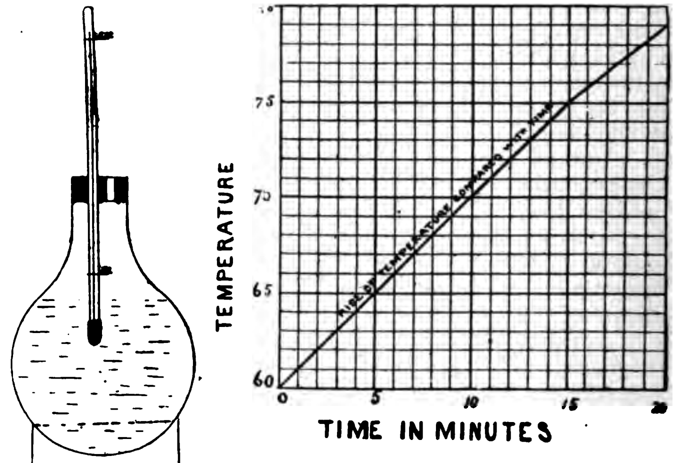


FIG. 4.

point where the 79 degrees line crosses the line representing the 20 minutes. Thus the result of the experiment which requires such a volume of language to explain is represented by a line, and can be read at a glance without having to decipher a complication of figures.

If the members of the trade who are unaccustomed to read diagrams will try and master this simple result, as plotted graphically, and giving temperature and time, they will experience no difficulty in following the more intricate results with which I propose to deal later.

## EXPERIMENT III.

Having described the apparatus used and the method of conducting the experiments, I will now proceed to explain the various results obtained from the different systems experimented on.

The little block boiler being very slow, none of the results obtained from it were tabulated. In the first experiment in which thermometers were used the system was connected on the cylinder and tank principle, but as the result would be a little complicated to begin with, I will defer experiments Nos. 1 and 2 till later, and commence with experiment No. 3.

The arrangement of the pipes in this experiment is shown by the drawing (Fig. 5), and will be at once recognised as the ordinary cylinder system. The boiler, it will be observed, is the steam jacket already described. The head of water on the boiler is 11 ft. 6 in.; length of flow pipe 8 ft.; length of return pipe 7 ft. 6 in.; volume of water circulating 23½ gallons; and to this must be added the water contained in the circulating pipes. It will be noted that the expansion pipe passes through the hot store cistern, but this need not be taken into account. Heat was supplied by a 4 in. H.P. gas stove.

Thermometers were fixed at points on the system as shown by A, H and M; A on the return pipe immediately on leaving the cylinder; H on the flow pipe immediately before it enters the cylinder; and M on the top of the cylinder. Readings were taken every five minutes; thus we were enabled to record the temperature of the water at different points at certain times, as tabulated below.

The temperature of the water in the system at the commencement of the experiment was 48 degs. To obtain a uniform temperature throughout it was found necessary to empty the system and refill it from the main before each experiment; for when this precaution was not taken certain thermometers recorded a fall of temperature during the experiment, which will be explained in detail when dealing with results obtained in experiments Nos. 1 and 2.

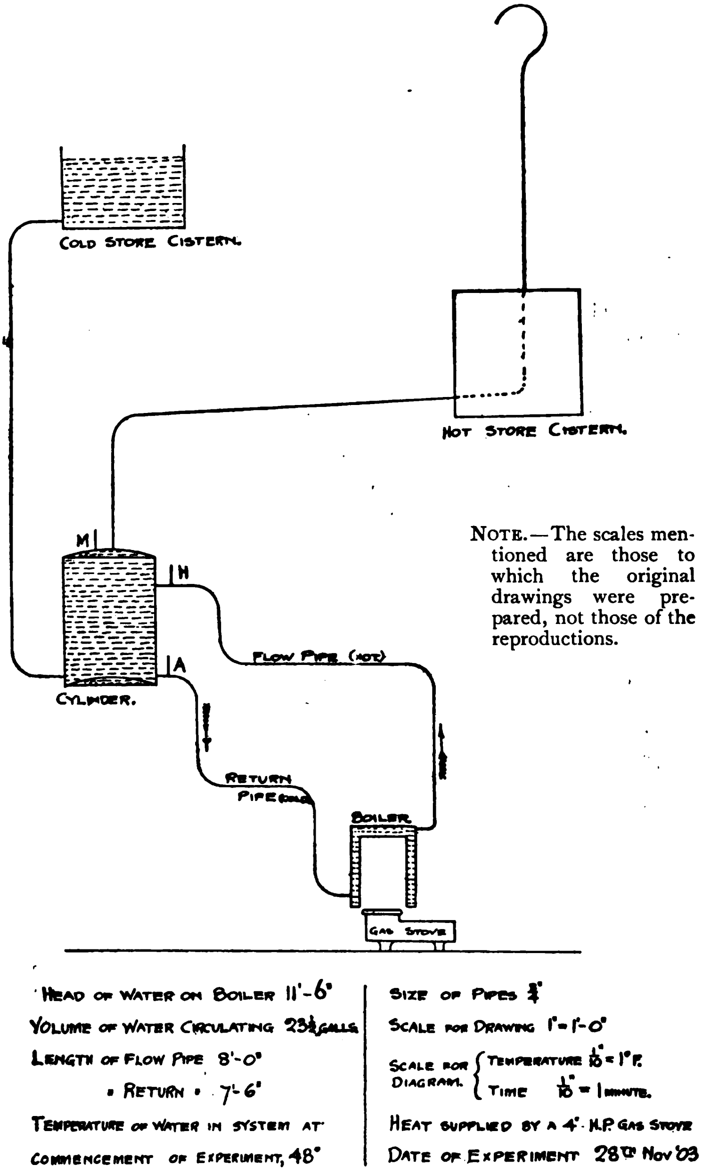

Cold Store Cistern.
Hot Store Cistern.
M
H
A
Cylinder.
Flow Pipe (hot)
Return Pipe (cold)
Boiler
Gas Stove
Head of Water on Boiler 11'-6"
Volume of Water Circulating 23½ galls
Length of Flow Pipe 8'-0"
" Return " 7'-6"
Temperature of Water in system at commencement of Experiment, 48°
Size of Pipes ¾"
Scale for Drawing 1"=1'-0"
Scale for Diagram. Temperature 1/10" = 1° F. Time 1/10" = 1 minute.
Heat supplied by a 4·H.P. Gas Stove
Date of Experiment 28th Nov '03

FIG 5 (EXPERIMENT NO. 3).—SHOWING ARRANGEMENT OF APPARATUS.

NOTE.—The scales mentioned are those to which the original drawings were prepared, not those of the reproductions.

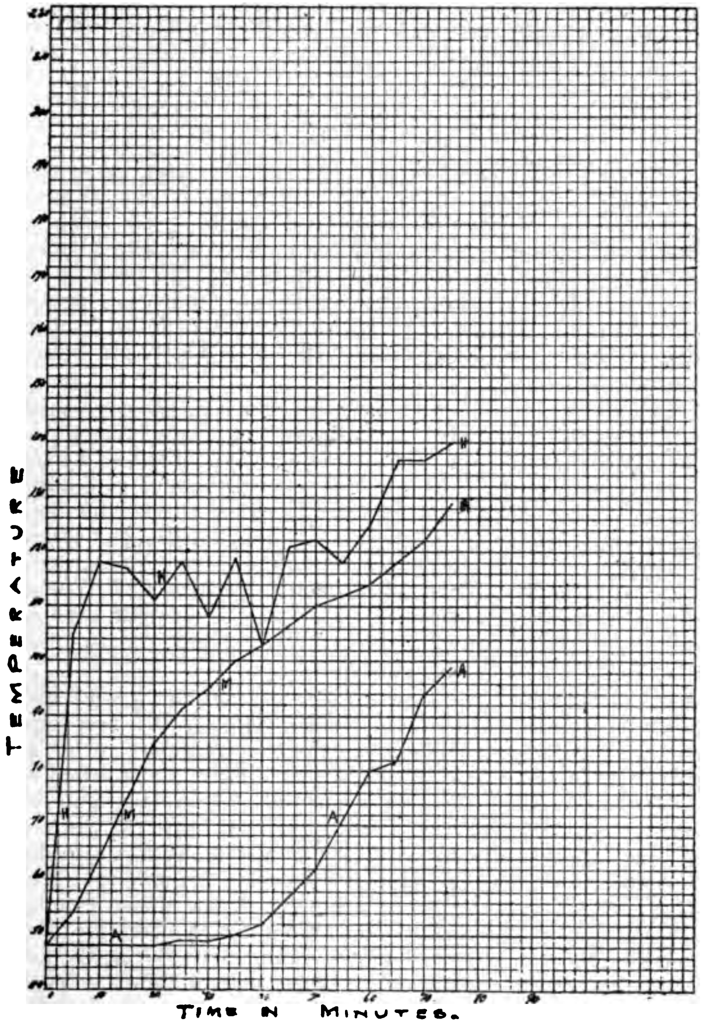


FIG. 5A (EXPERIMENT No. 3).—DIAGRAM SHOWING RESULTS PLOTTED.

## TABULATED RESULT OF EXPERIMENT No. 3.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 |
|---|---|---|---|---|---|---|---|---|
| Thermometer A | 48 | 48 | 48 | 48 | 48 | 49 | 49 | 50 |
| " H | 48 | 105 | 118 | 117 | 111 | 118 | 108 | 119 |
| " M | 48 | 54 | 64 | 75 | 85 | 91 | 95 | 100 |

| Time in minutes | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 |
|---|---|---|---|---|---|---|---|---|
| Thermometer A | 52 | 57 | 62 | 71 | 80 | 82 | 94 | 99 |
| " H | 103 | 121 | 122 | 118 | 125 | 137 | 137 | 140 |
| " M | 103 | 107 | 110 | 112 | 114 | 118 | 122 | 129 |

The above columns of figures represent the readings of the thermometers in degs. Fahr., but the result is complicated, troublesome to understand, and conveys little or no meaning to the practical mind. However, when plotted on squared paper, as shown by the accompanying diagram, Fig. 5A, the readings of each thermometer are represented by a curve, having a certain relation to each of the other curves, and in this form the result is simple, interesting and instructive, conveying at a glance a volume of meaning.

The scale for the original diagrams which is given on each should be carefully studied. The paper being divided into 1-5ths of inches, each vertical division represents two minutes; hence, 1 in represents ten minutes, 2 in. twenty minutes, and 3 in. thirty minutes. Each horizontal division represents 2 degs.; therefore 1 in. represents 10 degs., 2 in. 20 degs., 3 in. 30 degs., and so on. This is the scale used throughout all the diagrams to represent the behaviour of the thermometers when the system was circulating; but it was found necessary to employ a different scale to represent the temperatures as recorded during the "draw-offs," which will be given when dealing with them.

If the reader will now refer to the diagram, Fig. 5, and take H, which represents a thermometer fixed on the flow pipe entering the cylinder, and which recorded a temperature of 48 degs. at the commencement of the experiment, he will find on Fig. 5A the line which represents the travel of the thermometer starts from the point 48 on the first vertical line. At the end of five minutes, as will be seen by the tabulated result, H recorded a temperature of 105 degs., and at the end of ten minutes a temperature of 118 degs. had been reached. A line drawn through the points where the corresponding time and temperature lines intersect represents the travel of the thermometer during the first ten minutes of the experiment. At the end of fifteen minutes H stood at 117 degs., having fallen 1 deg. since last reading; and at the end of twenty minutes had fallen to 111 degs.

If we compare the line representing the travel of the thermometer during the first ten minutes with the line representing the travel of the thermometer during the next ten minutes, the contrast is very striking, and it will be seen how very effective this method is of showing the rise and fall of temperature during certain intervals of time.

Again, starting at the twenty minutes, it will be noticed that during the next five minutes the temperature is rising, until at the end of twenty-five minutes a temperature of 118 degs. is registered; but during the next interval the temperature is shown to be falling, until at the end of thirty minutes the thermometer registers a temperature of 108 degs. It will therefore be seen that when the curve is on the downward course it denotes a fall of temperature, and when it is travelling in an upward direction it indicates a rise of temperature.

What applies to this line applies also to the other two curves. Take, for example, M, which represents a thermometer fixed on the top of the cylinder, and which recorded a temperature of 48 degs. at the commencement of the experiment. From the tabulated result it will be seen that this thermometer registered a temperature of 54 degs. at the end of the first five minutes, and 64 degs. at the end of ten minutes. A line joining these points indicates the rise of temperature of the water at the top of the cylinder during the first ten minutes.

At this stage we may venture a little further afield, and compare the curves M and A with the curve H, which we have already studied. It will be noted that H rose much more quickly than M, and on looking at the curve A we see the line is horizontal for some distance, indicating that there was no change of temperature at that point during the first ten minutes, nor did A record any rise of temperature for a space of twenty minutes, as will be seen by the curve.

Having mastered the method of setting out the results graphically—temperature and time—we are in a position to read from the curves what is happening inside the system.

At the commencement of the experiment all the thermometers registered the same temperature. When heat was applied, H rose rapidly for the space of ten minutes, but did not maintain this rate of speed; for, as already stated, the temperature fell during the next ten minutes, and continued to rise and fall for a period of thirty minutes, during which time M made a steady rise. For a space of forty minutes A made little progress, the temperature of the water only rising 4 degs. in that time. After the forty minutes, however, A rose very quickly and uniformly till the end of the experiment.

It is interesting to notice also the behaviour of H after A commenced to rise. H also went up, and at the end of the experiment (75 minutes) H stood at 140 degs.; M at 129 degs.; and A at 99 degs.

No great importance need be attached to results obtained from this boiler considering the connections employed.

## EXPERIMENT IV.

In this experiment the copper tubular boiler was used. The 4 in. HP gas stove was replaced by an 8 in. HP stove, supplied by a $\frac{3}{4}$ in. pipe and stop-cock connected to the stove by a piece of $\frac{1}{2}$ in. indiarubber tube. According to Fletcher's catalogue, this stove should be supplied by a 1 in. pipe; therefore, with the connections used, the stove was burning somewhat below half its capacity.

TABULATED RESULT OF EXPERIMENT NO. 4.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 47 | 47 | 47 | 47 | 47 | 48 | 50 | 57 | 75 | 90 |
| (in degs. D | 47 | 99 | 130 | 140 | 139 | 135 | 132 | 141 | 140 | 147 |
| Fahr.) H | 47 | 80 | 122 | 136 | 135 | 132 | 128 | 138 | 138 | 143 |
| „ M | 47 | 51 | 67 | 89 | 104 | 110 | 117 | 123 | 127 | 131 |

| Time in minutes | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 101 | 109 | 118 | 124 | 129 | 136 | 144 | 153 | 158 |
| „ D | 157 | 165 | 174 | 178 | 183 | 189 | 194 | 200 | 209 |
| „ H | 153 | 162 | 170 | 175 | 180 | 186 | 189 | 194 | 202 |
| , M | 137 | 144 | 153 | 160 | 165 | 172 | 176 | 182 | 188 |

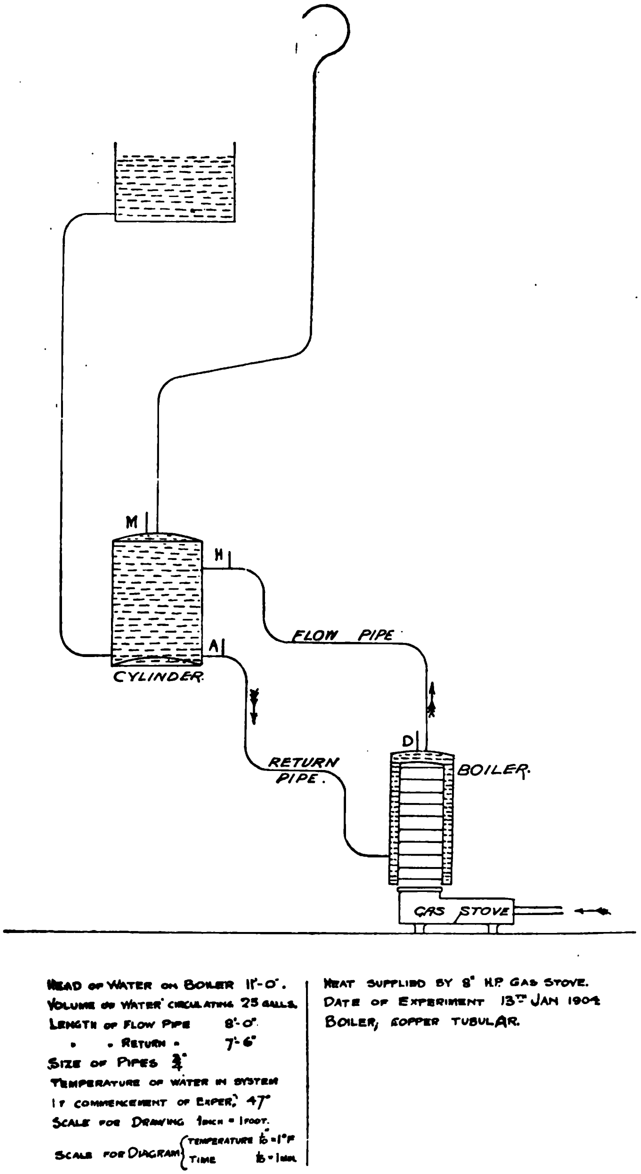
From the drawing (Fig. 6) it will be seen that the connections are exactly the same as in experiment No. 3, the only difference being the boiler and stove employed.

In this experiment, a thermometer having been fitted on the top of the boiler, the result is represented by four curves instead of three, as in the case of the previous result. Notwithstanding the altered conditions, and the noticeable difference in the rate at which the temperature rose, there is a great resemblance between the two sets of curves (Figs. 5A and 6A).

At the commencement of the experiment the temperature of the water in the system was 47 degs. When heat was applied the thermometer D, which was fixed on the top of the boiler, almost immediately commenced to rise, and one minute later H, which was fixed on the flow-pipe before entering the cylinder, 8 ft. away, also commenced to rise. At the end of the first five minutes D registered 99 degs., being a rise of 52 degs.; and H registered 80 degs., being a rise of 33 degs. On referring to the curves (Fig. 6A) it will be seen that these two thermometers rise in parallel lines for a space of 15 minutes, by which time D had reached 140 degs. and H 136 degs.; but as in the case of Experiment No. 3, a halt was called at this stage, and a slight fall of temperature, not so marked as in the previous result, is recorded.

The question naturally presents itself: What is the cause of this? Why does not the temperature at these points continue to rise unintermittently?

Before heat was applied, the entire volume of water was at rest; but immediately heat was applied the water was set in motion, the particles of water in the boiler expanded, and



Head of Water on Boiler 11'-0".
Volume of Water circulating 25 galls.
Length of Flow Pipe 8'-0".
" " Return " 7'-6"
Size of Pipes $\frac{3}{4}$"
Temperature of water in system
at commencement of exper.: 47°
Scale for Drawing 1inch = 1foot.
Scale for Diagram { Temperature $\frac{1}{10}$" = 1°F / Time $\frac{1}{10}$" = 1min

Heat supplied by 8" H.P. Gas Stove.
Date of Experiment 13th Jan 1904
Boiler, copper tubular.

Fig. 6 (Experiment No. 4).—Showing Arrangement of Apparatus.

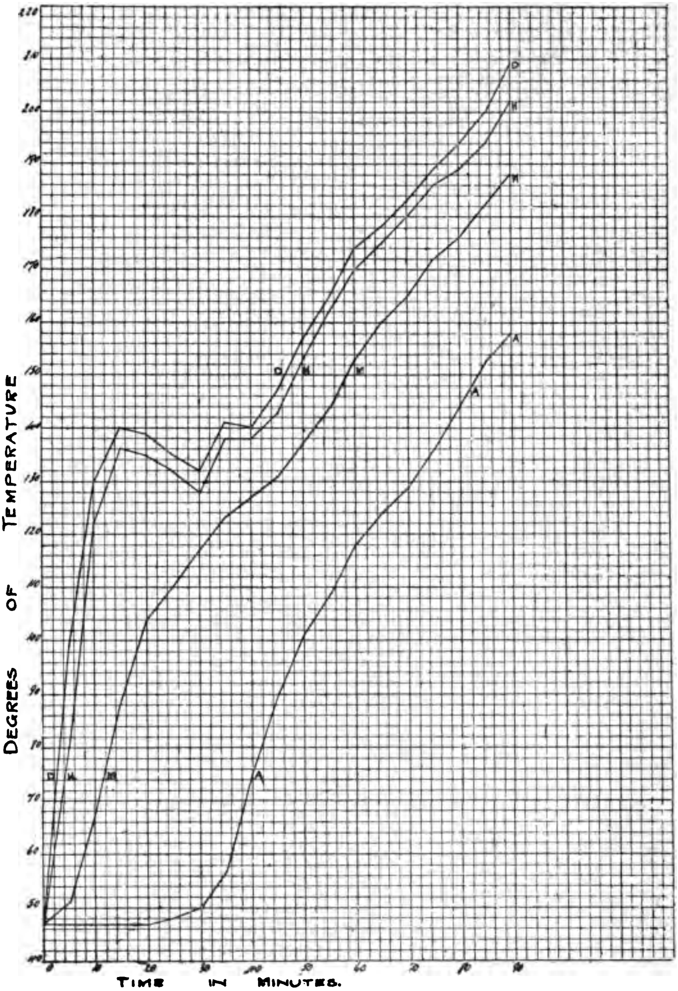


Fig. 6a (Experiment No. 4).—Diagram Showing Results Plotted.

were forced to the top by the colder and heavier particles entering by way of the return-pipe. This motion (which we plumbers know as "circulation"), being slow at first, allows the water to linger in the boiler and absorb a certain amount of heat; but as the rate of circulation increases, the water travels through the boiler at a greater speed and does not receive sufficient heat to maintain a continuous rise of temperature. Hence, for a certain period the water leaves the boiler at almost the same temperature; indeed, in some cases—as for example this and the previous result—a fall of temperature is registered.

In the present experiment it will be noticed that D recorded a loss of 8 degs., for at the end of 15 minutes the water was leaving the boiler at a temperature of 140 degs., and at the end of 30 minutes it was leaving the boiler at a temperature of 132 degs. After 40 minutes D again commenced to rise rapidly, and the reason for this will be found on referring to the curve A, Fig. 6A. During the first 20 minutes A recorded no rise of temperature, and for all practical purposes it may be said that A did not commence to rise until the lapse of thirty minutes, after which it rose very quickly. The water entering the boiler at this stage being of a higher temperature than it had been previously, enabled the boiler to also eject the water at a higher temperature, which had the natural effect upon D, by causing that thermometer to rise as shown by the curves.

From these two results it will be seen that D and H—which represent the temperature of the water leaving the boiler—did not rise in a continuous straight line as might have been expected; but when heat was applied the thermometer rose until a certain point had been reached (differing according to the power of the boiler), and there halted and marked time, until A, which was on the return-pipe, had wheeled into line, or, in other words, commenced to rise. At this period of experiment, when all the water in the system had been once round, D and H again commenced to rise, followed by M; and A will be observed to be travelling in approximately a parallel line to M so many minutes later.

Experiment No. 5 being exactly similar to No. 4 there is no necessity to dwell at length on this latter result, as it will be possible to go more into detail when studying Experiment No. 5, which also deals with a draw-off.

## EXPERIMENT V.

From the illustration, Fig. 7, it will be noticed that the apparatus is exactly similar to that used in Experiment No. 4. Length of flow pipe (already given) 8 ft.; length of return pipe 7 ft. 6 in.; volume of water circulating 25 gals. The cylinder was 2 ft. deep, the flow pipe entering the cylinder 8 in. from the top.

When heat was applied the usual thing happened (see Fig.

6A). D and H rose very quickly for a short period until a certain point was reached, after which no further rise of temperature was recorded until A commenced to rise, when D and H again made progress, and continued so doing in approximately parallel lines until the end of the experiment.

The distance between M and H should be noted for comparison with results obtained when the flow pipe was connected to the extreme top of the cylinder. During the experiment M kept about 20 degs. (on an average) below H, showing how, when drawing off, we are unable to draw off the hottest water from the top of the cylinder, as it has to pass through a column of colder water between the point where the flow pipe enters and the top of the cylinder. The water on its passage from one point to the other must of necessity part with some of its heat, and by the time the water reaches the top of the cylinder it is colder than when it entered the cylinder (in the present instance by about 20 degs.), as will be seen by the tabulated result given below.

### TABULATED RESULT OF EXPERIMENT NO. 5.

WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 55 | 69 | 87 |
| ,, D | 49 | 98 | 138 | 152 | 150 | 150 | 152 | 155 | 156 | 164 |
| ,, H | 49 | 85 | 134 | 152 | 149 | 150 | 152 | 154 | 154 | 161 |
| ,, M | 49 | 49 | 69 | 90 | 110 | 120 | 129 | 135 | 140 | 144 |

| Time in minutes | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 103 | 115 | 125 | 133 | 140 | 150 | 163 | 174 | 185 |
| ,, D | 174 | 186 | 194 | 200 | 202 | 207 | 213 | 217 | 220 |
| ,, H | 172 | 182 | 191 | 196 | 199 | 203 | 209 | 214 | 216 |
| ,, M | 150 | 160 | 166 | 174 | 184 | 190 | 196 | 202 | 206 |

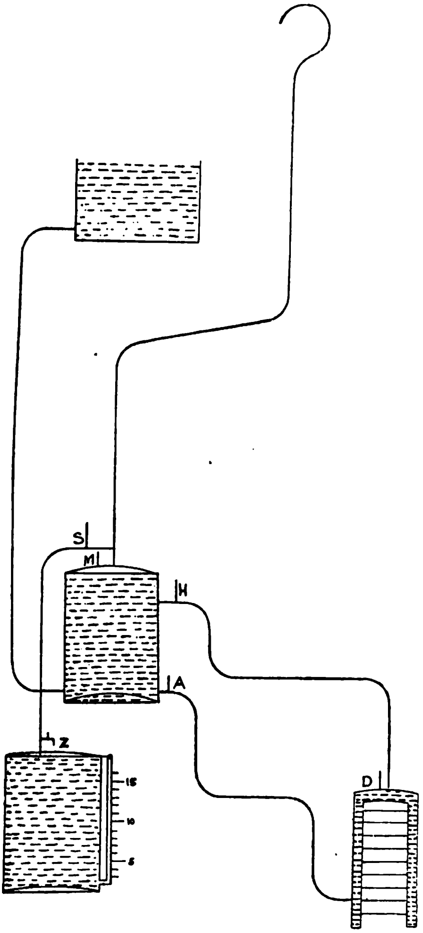
WHEN DRAWING OFF.

| Time in minutes | — | — | — | 91 | — | — | — | 92 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 154 | 130 | 120 | 119 | 110 | 107 | 101 | 99 | 91 | 90 |
| ,, D | 220 | 218 | 214 | 214 | 212 | 212 | 210 | 212 | 214 | 212 |
| ,, H | 216 | 214 | 212 | 212 | 211 | 210 | 210 | 209 | 208 | 205 |
| ,, M | 198 | 198 | 198 | 198 | 198 | 198 | 198 | 194 | 194 | 196 |

| Time in minutes | — | 93 | — | — | — | 94 | — | — | — | 95 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 90 | 87 | 89 | 90 | 93 | 92 | 92 | 87 | 87 | 87 |
| ,, D | 212 | 196 | 194 | 194 | 196 | 196 | 194 | 192 | 190 | 192 |
| ,, H | 202 | 200 | 198 | 197 | 196 | 196 | 195 | 193 | 192 | 190 |
| ,, M | 150 | 124 | 104 | 106 | 105 | 104 | 100 | 96 | 95 | 93 |

It is interesting to notice that the curves are almost identical with those of the previous result, except that the rise is a little quicker, this, no doubt, being due to a better supply of gas, less gas being used in other parts of the building than on the evening when experiment No. 4 was carried out.

This system will be recognised as the one usually adopted for small houses, and is what might be called the "popular" method. But notwithstanding the fact that everyone connected with the



Head of Water on Boiler 11'-0".
Volume of Water Circulating 25 Galls.
Length of Flow-Pipe 8'-0"
" Return 7-6"
Size of Pipes 3/4
Temperature of Water at commencement of Experiment 49°
Scale for Drawing 1" = 1-0"
Scale for Diagram. Temperature 1/10" = 1° F
Time when system closed 1/10 = 1 min
during draw off 4/5 = 1

Scale for Gallons 1/5" = 1 Gall.
Quantity drawn off 20 Galls.
Rate of Draw off, 4 Galls. per min
Heat supplied by 8" H.P Gas Stove
Boiler, Copper Tubular.
Date of Experiment 22nd Jan '04
Average Temperature of Water drawn off 152°

Fig. 7 (Experiment No. 5).—Showing Arrangement of Apparatus.

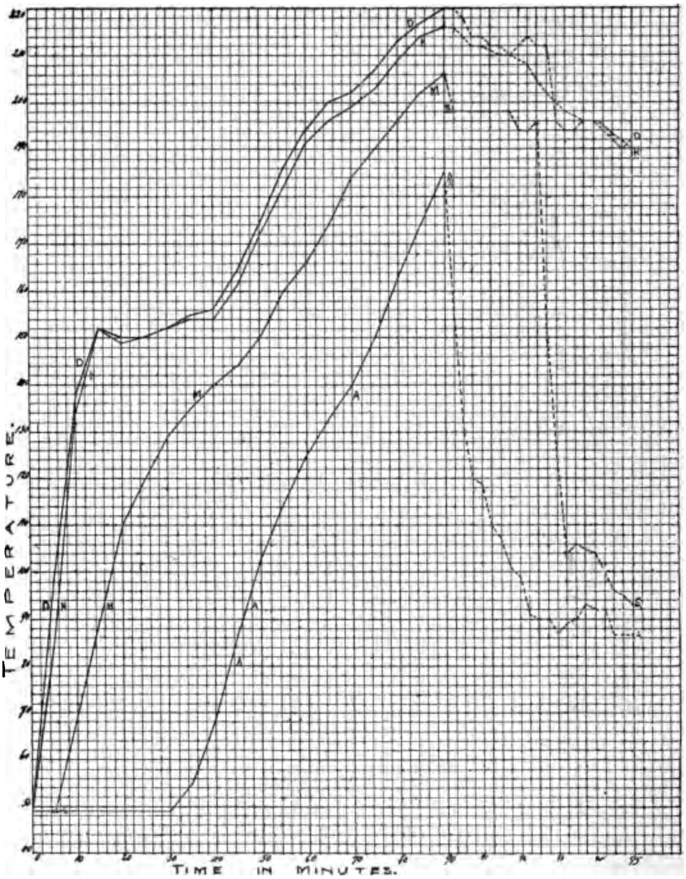


FIG. 7A (EXPERIMENT NO. 5).—DIAGRAM SHOWING RESULTS PLOTTED.

trade is intimately acquainted with this system, the result of the experiment brings to notice one or two interesting points which might be overlooked, if not unlooked for altogether.

It will be seen that at the end of 90 minutes D stood at 220 degs., being 8 degs. above the normal boiling point of water, illustrating the rise of the boiling point as the pressure is increased. The cistern in this instance was 11 ft. above the boiler; a pressure of approximately 4½ lbs. per square inch was consequently exerted on the boiler. With this additional pressure the boiling point is raised from 212 degs. to 220 degs.

In that admirable little work entitled "Technical Plumbing," by S. Barlow Bennett, there is given a table of the boiling points of water, under various heads, which will bear repetition here.

| | | | |
|---|---|---|---|
| Water under the pressure of the atmosphere (14·7 lbs. per sq. in.) boils at | | | 212 degs. Fahr. |
| Water under a head of | 10 ft. | boils at | 218 ,, |
| ,, ,, | 20 ft. | ,, | 236 ,, |
| ,, ,, | 30 ft. | ,, | 246 ,, |
| ,, ,, | 40 ft. | ,, | 254 ,, |
| ,, ,, | 50 ft. | ,, | 261 ,, |
| ,, ,, | 60 ft. | ,, | 268·5 ,, |

(NOTE.—For every 10 ft. of head add 4·3 lbs.)

From this table it will be seen that water in a boiler subjected to 20 ft. head will attain a temperature of 236 degs.; whilst if subjected to 40 ft. head a temperature of 254 degs. is attained before boiling point is reached.

It may be to a certain extent correct to term this system of heating "low-pressure," but it should be borne in mind that under these conditions (the water in the boiler being subjected to a head pressure) the kitchen boiler may become practically a steam boiler. Under such conditions some precaution should be taken to avoid the danger of explosion. Even at the risk of alarming my good fellow citizens, it may here be said that in Belfast a safety valve on a kitchen boiler is all but unknown!

The reader will at this stage commence to realise the importance of these curves as indicative of what is going on inside the system. The water leaving the boiler is the hottest, therefore D stands highest on the diagram. H, which is on the flow pipe 8 ft. away from the boiler, follows in the footstep of D, there being only a few degrees of difference in the temperature at these two points throughout the experiment. When the hot water enters the cylinder it must pass through a column of colder water in the cylinder, which causes M to remain at a lower temperature than H. Therefore M travels at a lower level than D or H throughout, whilst A, which is on the bottom of the cylinder, remains at the same temperature—represented by a straight horizontal line—for a period of 30 minutes, and when thermometer A begins to rise it travels in an approximately parallel line to M; which goes to show that certain particles of heated water are having the same effect on A as they had on M so many minutes previously, a slight allowance being made for loss of heat by radiation.

The curves enable us to compare the behaviour and temperature of the water at certain points and at different times in a way that would be otherwise impossible.

At the end of 90 minutes A registered 185 degs., M 206 degs., H 216 degs., and D 220 degs., there being a difference of 35 degs. between the highest and the lowest. At this stage the tap Z was opened, and 20 gals. of water drawn off at the rate of 4 gals. per minute. The travel of the thermometer during the draw-off is represented by the dotted lines to the right of the diagram. Dotted lines are employed throughout all the diagrams to represent the behaviour of the thermometers while water was being drawn off.

The scale for the diagram representing the draw-offs is given with each result. Each vertical division represents 1 gal., and each horizontal division represents 2 degs. The time in minutes will be found figured along the first horizontal line of each diagram. The behaviour of the thermometers, which of course indicates what is going on inside the system during the draw-off, has proved very interesting and instructive.

It might be supposed that the cold water rushing in at the bottom of the cylinder finds its way down the return pipe to the boiler, chills the boiler, and rushes up the flow pipe. But this does not happen, as will be seen by looking at the dotted curves which represent the temperature of the water at the various points during the draw-off. From these curves we see that on opening a tap the cold water entering makes for the nearest way out. This is an important point to bear in mind when taking off branches for hot water supplies.

It is not to be supposed that because hot water is lighter than cold that the latter will allow the hot to float on the top until all the hot water is drawn off before the cold water tries to escape. We must keep in mind that the water rushes in at the bottom of the cylinder under pressure, and every particle of water in the system being under pressure, they all converge towards the opening. Hence it follows as a matter of course that the particles in the most direct route (whether they be hot or cold) get there first. The plumber must aim at making it as difficult as possible for the cold water, and as easy as possible for the heated water, to reach the branch.

To accomplish this he must be possessed of a thorough knowledge of the specific gravity of water at different temperatures, the effect of friction on water when travelling through pipes, and the counteracting influences head pressure may exercise. And not alone must the plumber have a knowledge of these matters, but he must also be able to apply such knowledge judiciously when fitting up a system of hot water apparatus, so that the forces concerned may not counteract each other. The pipes, fittings and connections should be arranged in such a way that all these factors work in harmony, so that water when heated may be drawn off at its highest temperature.

The fact that hot and cold water find their respective levels holds good when the volume is at rest or circulating, but immediately a tap is opened the equilibrium (if it might be so termed) is upset and a mixing operation goes on, the extent of the mixing depending of course upon circumstances.

In referring to the dotted curves (Fig. 7A) it will be noticed that the first 10 gals. drawn off, which are represented by the dotted line S, were practically at the same temperature, 198 degs. The question may naturally be asked, How do you know this? A thermometer was fixed on the branch at S, and readings taken as every gallon was drawn off. Before the tap was opened the temperature recorded by each thermometer was noted. At the end of the first gallon the temperature was again recorded, the same being done at the end of the second gallon, also at the third, and so on.

During the drawing off of the first 10 gals. the thermometer S stood almost at the same temperature; hence the temperature of the first 10 gals. is represented by a straight horizontal line, except for a fall of 4 degs. for the eighth and ninth gallon. At the end of 10 gals. the unexpected happened—a sudden fall of temperature. It would not have been unreasonable to have expected a gradual fall, but a drop of 92 degs. during the draw-off of the next 3 gals. was a result that might not have been looked for. During the time the next 7 gals. was being drawn off the thermometer continued to fall very slowly.

If we now turn our attention to D, we find that during the draw-off the thermometer on the top of the boiler also fell, but not to the extent that some would have us believe; for it is held by a great many in connection with the trade that cold water rushes in at the bottom of the cylinder and down the return-pipe into the boiler; but that is not so. The cold water entering at the bottom of the cylinder no doubt finds its way down the return-pipe into the boiler, but does not travel at a break-neck speed, only just circulating in the ordinary way at a rate which we will consider later. H behaved similarly to D, and A fell throughout the draw-off.

Again turning our attention to S, we might with profit ask ourselves why the temperature remained practically steady during the drawing off of 10 gals., then fell suddenly, paused, and again fell slowly while 7 gals. more were drawn off. The hot water being stored at the top of the cylinder, on opening the tap the cold water entering at the bottom of the cylinder forces the hot water out. During the time the first number of gallons were being drawn off a mixing operation was going on at the bottom of the cylinder. By the time 10 gallons had been drawn off the mixing had extended to the top of the cylinder, and from this period on mixed water was drawn off.

At this stage the water drawn off was measured by means of an ordinary measure, but a cylinder fitted with a glass tube and graduated to gallons, as shown on the drawing (Fig. 7), was employed for measuring purposes in the succeeding experiments.

## EXPERIMENT VI.

It has been claimed that the last system experimented on might be improved by connecting the flow to the expansion by means of a bridge-piece (sometimes called a bye-pass), as shown by the drawing (Fig. 8).

To prove the truth or otherwise of this claim, the flow-pipe was connected to the expansion by means of a ¾ in. bridge-piece. Heat was supplied by the 8 in. h.p. stove, which it may be said was used throughout all the remaining experiments dealt with in these articles.

Up to this time no record was kept of the gas consumption, but that such a record would be desirable made itself evident. The supply to the stove was accordingly connected to a spare meter in the adjoining room by a ¾ in. pipe, connected to the stove by ½ in. indiarubber tube, so that the stove was being supplied under the same conditions as it had been previously. The state of the meter being taken before and after each experiment the consumption of gas will be given with each result.

When heat was applied, again the usual thing happened (see Fig. 8A). D and H jumped up, and were closely followed by J, which was fitted on the bridge-piece, showing that the water was passing through the bridge-piece, and not entering the cylinder at the low level. And when we come to think of it this is only natural. The heated particles, when being forced up, take the most favourable course to get to the top; the cold water in the cylinder, pressing against the flow entering at the lower level, offers a certain amount of resistance to the heated water entering at that point, causing it to turn up the bridge-piece and enter the cylinder at the higher level.

If we compare the result obtained in the experiment with that of the previous one we find no great difference to which importance can be attached, except that A was a little lower in comparison with D than was the case when the flow entered at a lower level without a bridge-piece.

On looking at the curves it will be noticed that at certain times H (on the flow) stood higher than D (on the boiler). This condition of things when the temperature was rising being impossible, the reason was looked for and found to be a defect of the thermometer, the capillary tubes not being of uniform bore. To avoid this in future experiments the thermometers were tested and standard thermometers used at these points.

During the circulation the thermometer J fluctuated slightly throughout the experiment. This, coupled with the fact that J stands lower than H (both in Experiments 6 and 6 A), suggests a short circuit circulation out of the cylinder through the bridge-piece; and instead of water entering the cylinder where the flow enters at the low level, it was actually coming out of the cylinder at this point, and, passing through the bridge-piece, re-entered the cylinder at the higher level.

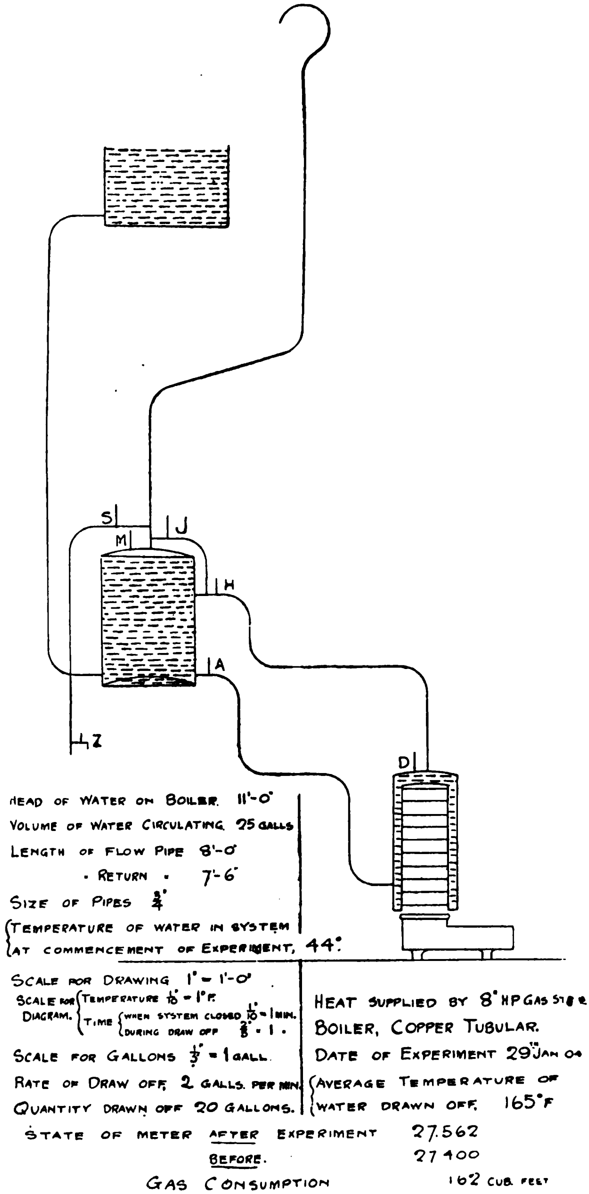
At the end of 85 minutes the tap Z was opened and 20 gallons of water drawn off at the rate of 2 gallons per minute. But before the 20 gallons were drawn off the cold store cistern was emptied (by accident it was only half full at the commencement), and during the later period of the draw-off the water was only being drawn as quickly as the ball-cock would deliver it. As this has a direct bearing on the result the fact is here mentioned.

The result obtained during the draw-off brought to the surface a very important point, and one well worthy of serious consideration. On looking at the curves (Fig. 8A) it will be noticed that on opening the tap Z the thermometer S, which was on the branch, had gone up from 114 to 200 degrees during the first gallon. This point needs no explanation when we consider that during the heating process the water at this point was at rest, being heated principally by conduction; but on opening the tap the hot water commenced to flow, causing the thermometer to rise.

At the end of the second gallon a temperature of 206 degs. was recorded by S, while M at the same instant stood at 204 degs., and J at 212 degs., and suggests a mixture of water from M and J being drawn off at the intermediate temperature. This is what would be expected; but a little later on, at the end of, say, 9 gallons, if we look at the curve, J had dropped to 160 degs., while M stood at 202 degs., and the water was passing out of the branch at 185 degs., being 17 degs. colder than the water at the top of the cylinder.

At first sight this appears to be impossible, and if we look at D and H we see that the water was leaving the boiler at 208 degs., whilst H indicated a temperature of 212 degs., which proves that cold water was not being drawn from the boiler, confirming the idea that the seemingly impossible was happening. But on looking a little closer at the diagram and giving the matter a little study the result is just what we ought to have expected. Unfortunately plumbers as a rule do not give important subjects such as the one we are now dealing with the necessary thought, but are prone to look only on the surface.

What then actually happened during the draw-off? Is it possible that colder water was drawn out of the cylinder through



HEAD OF WATER ON BOILER. 11'-0"
VOLUME OF WATER CIRCULATING. 25 GALLS
LENGTH OF FLOW PIPE 8'-0"
" RETURN " 7'-6"
SIZE OF PIPES $\frac{3}{4}$"
{TEMPERATURE OF WATER IN SYSTEM AT COMMENCEMENT OF EXPERIMENT, 44°.

SCALE FOR DRAWING 1" = 1'-0"
SCALE FOR DIAGRAM. {TEMPERATURE $\frac{1}{10}$" = 1° F.
TIME {WHEN SYSTEM CLOSED $\frac{1}{10}$" = 1 MIN.
DURING DRAW OFF $\frac{2}{8}$" = 1 "
SCALE FOR GALLONS $\frac{1}{3}$" = 1 GALL.
RATE OF DRAW OFF, 2 GALLS. PER MIN.
QUANTITY DRAWN OFF 20 GALLONS.

HEAT SUPPLIED BY 8" HP GAS STOVE BOILER, COPPER TUBULAR.
DATE OF EXPERIMENT 29TH JAN 04
{AVERAGE TEMPERATURE OF WATER DRAWN OFF. 165° F

STATE OF METER AFTER EXPERIMENT 27.562
BEFORE. 27 400
GAS CONSUMPTION 162 CUB. FEET

FIG. 8 (EXPERIMENT NO. 6).—SHOWING ARRANGEMENT OF APPARATUS.

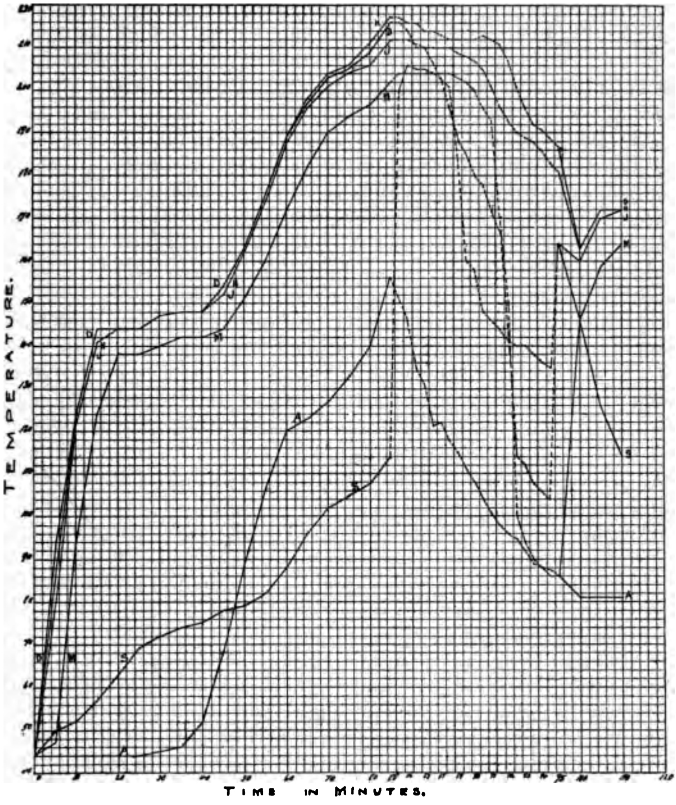


FIG. 8A (EXPERIMENT NO. 6).—DIAGRAM SHOWING RESULTS PLOTTED.

the bridge-piece than that contained in the top of the cylinder? There is a theory accepted amongst plumbers that "hot water being lighter than cold the hot water floats on the top," and that "all the hot water must be drawn off first." It has been stated in the notes on Experiment V., and it will bear repeating, that this theory holds good when the water is at rest or circulating, as may be proved by referring to the curves in any of the diagrams; but immediately a tap is opened this state of affairs is upset, all the particles rushing towards the exit.

When the tap Z was opened the cold water entered at the bottom of the cylinder mixing with the hot water in the cylinder. During the first stage of the mixing process the hot water at the top of the cylinder had been escaping through the pipe from the extreme top, and also through the bridge-piece. When the mixing had extended as far up the cylinder as the point where the flow-pipe entered at the low-level, the mixture which was colder than the water at the top of the cylinder was drawn through the bridge-piece, and mixed with the water drawn from the top of the cylinder at the point where the bridge was connected to the expansion, thus giving an intermediate supply, represented by the middle dotted line S.

The question may be asked "Was all the water that passed through the bridge-piece drawn from the cylinder?" It is possible to show that it was not, but that the greater portion was. It may be further asked "Why was the water not drawn from the boiler?" The water circulating no doubt delivered a quantity of water up the flow-pipe at a very high temperature, as will be seen on referring to H; but it must be remembered that water when circulating travels slowly; the demand on the bridge-piece being greater than the supply coming through the flow, drawing from the cylinder presented the least difficulty, with the natural result that the water was drawn from that source.

But why was water drawn through the bridge-piece at all? Two $\frac{3}{4}$-inch tees were fixed on the top cylinder, the bridge-piece being connected to the lower and the branch to the upper tee. It might be expected that the water would have been drawn the most direct way, *e.g.*, the top of the cylinder. We have to keep in mind the fact that water does not flow to a hole and out in a parallel cylindrical form, but becomes contracted by the force of the converging layers of water; so that the issuing stream takes the shape of a cone at a distance in of about half the diameter of the pipe. This is called "vena contracta." A partial vacuum being formed in the present case immediately after the entrance to the $\frac{3}{4}$-inch tee, the water in the bridge-piece, aided by pressure, rushed in to supply this vacuum. Thus a siphonic action was set up, the bridge-piece acting as a siphon leg throughout the "draw-off."

A little further on in the "draw-off" the previous order of things was reversed. The water flowing through the bridge-piece, being at a higher temperature than the water at the top of the cylinder, the result was that hotter water was being drawn off at this stage than that at the top of the cylinder. For example, when the water at M stood at 94 degs., the water passing through the bridge-piece was at a temperature of 140 degs., and an intermediate mixture at 112 degs. was being drawn off.

How is this state of affairs explained? It has already been said that all the water passing through the bridge-piece was not drawn from the cylinder, a portion being drawn through the flow-pipe from the boiler at such a rate as the travel of water circulating permitted. Thus a mixture of water from the cylinder and from the boiler was passing through the bridge-piece during the draw-off, this mixture mixing with the water drawn from the top of the cylinder. It will therefore be seen that water was being drawn from three sources—(*a*) the top of the cylinder; (*b*) the cylinder at the lower level, and (*c*) from the boiler. When the temperature of the water was reduced to a certain point the supply of hot water circulating from the boiler mixed with the cold water that was being drawn from the cylinder, the resulting mixture being higher in temperature than the water at the top of the cylinder at this period. This mixture of water (passing through the bridge-piece) at a higher temperature, mixing with the water drawn from the top of the cylinder at a lower temperature, gave a supply of water drawn off at an intermediate temperature, as again indicated by the middle dotted line S.

It will be noticed that the thermometer on the branch piece (S) showed a rise of temperature during the time the last gallon (the 20th) was being drawn off. About the fifteenth gallon the water commenced to run very slowly. This is accounted for by the fact already stated—the cold store cistern was only half full. Before twenty gallons were drawn off the store of water had become exhausted, and when the last gallon was being drawn off the water was running very slowly, with the result that the hot water circulating from the boiler formed the major portion of the water drawn off at this period, as is evidenced by the fact that at this stage there was only a difference of 17 degs. between the temperature of the water at D, on the top of the boiler, and the water passing through the branch at S.

It is interesting to notice, when the tap was shut off, how very quickly the water at the different temperatures found its respective positions, as shown by the solid lines on the extreme right of the diagram (Fig. 8A).

## TABULATED RESULT OF EXPERIMENT No. 6.

WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 |
|---|---|---|---|---|---|---|---|---|
| Thermometer A | 44 | 44 | 44 | 44 | 44 | 44 | 45 | 46 |
| ,, D | 44 | 94 | 124 | 144 | 144 | 144 | 147 | 148 |
| ,, H | 44 | 88 | 124 | 144 | 144 | 144 | 147 | 148 |
| ,, J | 44 | 80 | 122 | 141 | 144 | 144 | 147 | 148 |
| ,, M | 44 | 47 | 94 | 124 | 138 | 138 | 140 | 142 |
| ,, S | 44 | 50 | 52 | 57 | 63 | 69 | 72 | 74 |

| Time in minutes | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 |
|---|---|---|---|---|---|---|---|---|
| Thermometer A | 52 | 68 | 89 | 107 | 120 | 123 | 127 | 133 |
| ,, D | 148 | 154 | 163 | 176 | 189 | 197 | 203 | 205 |
| ,, H | 148 | 154 | 163 | 176 | 189 | 198 | 204 | 206 |
| ,, J | 148 | 152 | 162 | 174 | 188 | 196 | 201 | 204 |
| ,, M | 142 | 144 | 151 | 160 | 172 | 182 | 190 | 194 |
| ,, S | 75 | 78 | 79 | 82 | 88 | 96 | 102 | 105 |

| Time in minutes | 80 | 85 | 90 | 95 | 100 | 105 | 110 |
|---|---|---|---|---|---|---|---|
| Thermometer A | 140 | 156 | | 87 | 81 | 81 | 81 |
| ,, D | 209 | 216 | Draw-off | 181 | 163 | 172 | 172 |
| ,, H | 211 | 217 | | 187 | 163 | 172 | 172 |
| ,, J | 206 | 212 | | 164 | 160 | 170 | 172 |
| ,, M | 197 | 202 | | 86 | 146 | 159 | 164 |
| ,, S | 108 | 114 | | 164 | 146 | 126 | 114 |

WHEN DRAWING OFF.

| Time in minutes | — | 86 | — | 87 | — | 88 | — | 89 | — | 90 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 156 | 150 | 146 | 135 | 131 | 121 | 122 | 118 | 115 | 111 |
| ,, D | 216 | 214 | 210 | 210 | 210 | 210 | 210 | 209 | 208 | 207 |
| ,, H | 217 | 216 | 216 | 214 | 214 | 213 | 212 | 212 | 212 | 212 |
| ,, J | 212 | 212 | 211 | 210 | 207 | 203 | 201 | 184 | 160 | 158 |
| ,, M | 204 | 204 | 204 | 204 | 204 | 204 | 204 | 203 | 202 | 200 |
| ,, S | 200 | 206 | 205 | 205 | 204 | 203 | 196 | 188 | 185 | 180 |

| Time in minutes | — | 91 | — | 92 | — | 93 | — | 94 | — | 95 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 108 | 104 | 101 | 98 | 96 | 95 | 92 | 89 | 88 | 87 |
| ,, D | 205 | 201 | 196 | 193 | 190 | 189 | 188 | 186 | 183 | 181 |
| ,, H | 213 | 212 | 211 | 207 | 201 | 196 | 192 | 191 | 189 | 187 |
| ,, J | 148 | 146 | 144 | 141 | 140 | 140 | 138 | 136 | 135 | 164 |
| ,, M | 196 | 193 | 170 | 150 | 100 | 94 | 90 | 88 | 86 | 86 |
| ,, S | 178 | 172 | 167 | 140 | 114 | 112 | 108 | 106 | 104 | 164 |

## EXPERIMENT VIA.

The question being asked, "Would the same result be obtained on every occasion?" it was decided to conduct a second experiment on the same system.

From the curves (shown in accompanying diagram, Fig. 9A) it will be seen at a glance that the results are for all purposes concordant with those obtained in Experiment No. 6, Fig. 8A. After eighty minutes a fall of temperature is indicated by some of the curves. This was due to the gas being lowered to prevent the water in the boiler rising above 212 degrees (normal boiling point); otherwise the curves are almost the same as those of the prior result.

It might appear from a casual glance at the curves representing the period of the draw-off that the boiler was not chilled to the same extent as in Experiment No. 6. On looking at the time scale it will be seen that in the latter experiment the water in the boiler stood at 217 degs. at the commencement of the draw-off (85 minutes), and at a temperature of 181 degs. at the end of the draw-off, ten minutes later; but it will be noticed that the draw-off in Experiment No. 6A only occupied five minutes, being at the rate of four gallons per minute. Before the draw-off the temperature of the water in the boiler was 208 degs., and at the end of the draw-off (five minutes later) it was leaving the boiler at the same temperature—a proof that water travels slowly when circulating, and that the cold water entering at the bottom of the cylinder does not rush down the return-pipe into the boiler.

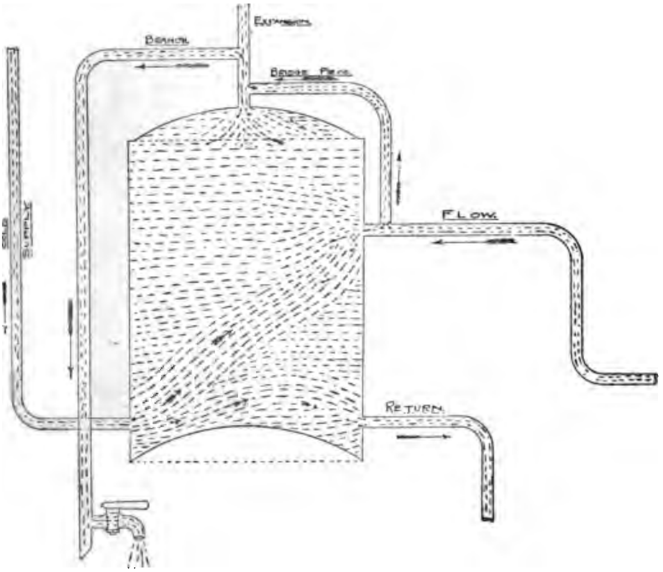
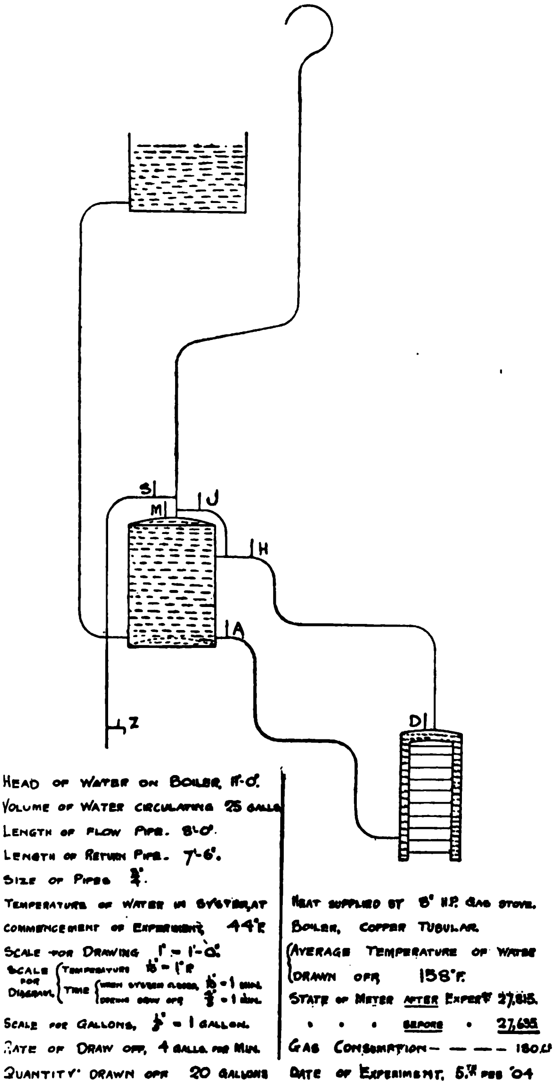


Diagram Showing Direction of Flow during Draw-off in Experiments 6 & 6A.

The next reading, which was taken five minutes later (or



HEAD OF WATER ON BOILER, 11'-0".
VOLUME OF WATER CIRCULATING 25 GALLS
LENGTH OF FLOW PIPE. 8'-0".
LENGTH OF RETURN PIPE. 7'-6".
SIZE OF PIPES 3/4".
TEMPERATURE OF WATER IN SYSTEM, AT COMMENCEMENT OF EXPERIMENT, 44°F.
SCALE FOR DRAWING 1" = 1'-0".
SCALE FOR DIAGRAM. TEMPERATURE 1/16" = 1°F.
SCALE FOR DIAGRAM. TIME: WHEN SYSTEM CLOSED, 1/16" = 1 MIN.
SCALE FOR DIAGRAM. TIME: DURING DRAW OFF 3/8" = 1 MIN.
SCALE FOR GALLONS, 1/8" = 1 GALLON.
RATE OF DRAW OFF, 4 GALLS. PER MIN.
QUANTITY DRAWN OFF 20 GALLONS

HEAT SUPPLIED BY 8" H.P. GAS STOVE.
BOILER, COPPER TUBULAR.
AVERAGE TEMPERATURE OF WATER DRAWN OFF, 158°F.
STATE OF METER AFTER EXPERT. 27,815.
" " " BEFORE " 27,635
GAS CONSUMPTION — — — — 180 C.F.
DATE OF EXPERIMENT, 5TH FEB '04

FIG. 9 (EXPERIMENT NO. 6A).—SHOWING ARRANGEMENT OF APPARATUS.

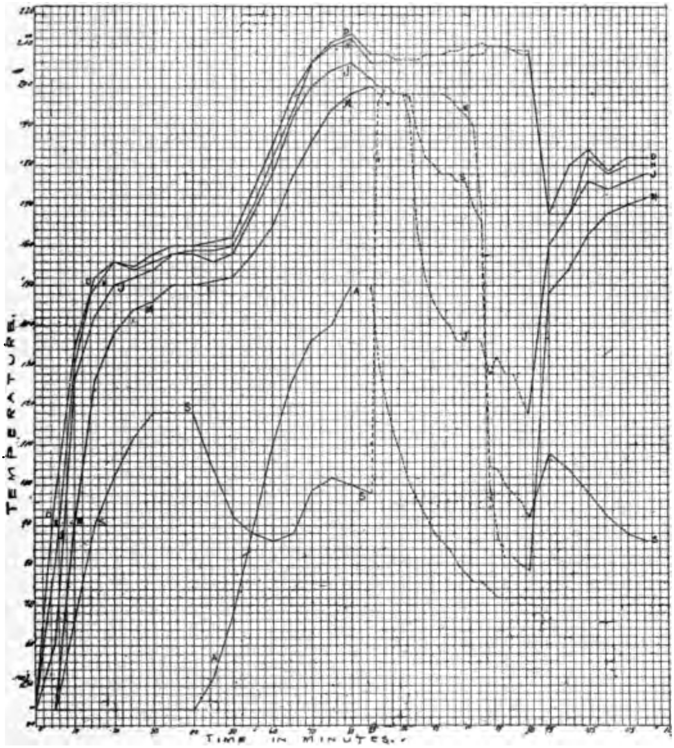


FIG. 9A (EXPERIMENT NO. 6A).—DIAGRAM SHOWING RESULTS PLOTTED.

ten minutes from the commencement of the draw-off), showed that the temperature of the water in the boiler had fallen to 168 degrees, whilst in experiment No. 6 it was 163 degs., which goes to prove that in an equal space of time the temperature of the water in the boiler was reduced to about the same extent. The rate of the draw-off was quicker in one case than the other, but on the time scale there was only a difference of a few degrees.

The fact that the cold water had not reached the top of the boiler at the end of the draw-off, which occupied five minutes, should, in the writer's opinion, prove the fallacy of the idea that when a tap is opened the cold water rushes down the return-pipe into the boiler and up the flow-pipe during the time water is being drawn off.

The experiment was continued for thirty minutes after the draw-off, and again it will be observed how very quickly the water at the different temperatures found its proper position. The curves show that the behaviour of the water as indicated by the thermometers was exactly similar to what it was when heat was first applied. The coldest water was at the bottom of the cylinder; the curve A being a straight line for a certain period; D and H jumped up to a certain point, and then marked time until A commenced to rise—thus proving that water always behaves in the same manner when subject to the same conditions. It will also be observed from the plotted result (Figs. 8A and 9A) that the curves J, M, and S cross each other at the same instant, proving the accuracy of the readings and serving as a check on the result.

Some of the students had doubts whether water was drawn from the cylinder through the bridge-piece during the draw-off in the last two experiments. Being anxious to remove doubts and to prove theory by fact, the lead bridge-piece was removed, and a glass bridge-piece substituted. When the tap was opened water was observed to pass through the glass tube, which of course removed all doubt on the subject.

A drawing is given on page 33 showing the direction of the flow of water during the draw-off in the two previous experiments.

It may be stated that the gas was kept burning (full) during the time water was being drawn off in all the experiments.

## TABULATED RESULT OF EXPERIMENT No. 6A.

WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| ,, D | 44 | 97 | 134 | 152 | 156 | 155 | 158 | 160 | 160 |
| ,, H | 44 | 80 | 130 | 148 | 156 | 154 | 156 | 158 | 159 |
| ,, J | 44 | 60 | 126 | 142 | 150 | 152 | 154 | 158 | 158 |
| ,, M | 44 | 44 | 90 | 126 | 138 | 144 | 146 | 150 | 150 |
| ,, S | 44 | 44 | 66 | 90 | 102 | 112 | 118 | 118 | 118 |

| Time in minutes | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 52 | 68 | 90 | 110 | 126 | 136 | 140 | 150 | 150 |
| ,, D | 161 | 162 | 174 | 185 | 198 | 206 | 211 | 213 | 208 |
| ,, H | 159 | 160 | 170 | 182 | 196 | 206 | 210 | 212 | 206 |
| ,, J | 156 | 158 | 168 | 178 | 192 | 200 | 204 | 206 | 202 |
| ,, M | 151 | 152 | 158 | 165 | 177 | 186 | 194 | 198 | 200 |
| ,, S | 104 | 92 | 88 | 86 | 88 | 99 | 102 | 100 | 98 |

| Time in minutes | | 90 | 95 | 100 | 105 | 110 | 115 | 120 |
|---|---|---|---|---|---|---|---|---|
| Thermometer A | Draw-off | 72 | 72 | 72 | 72 | 72 | 72 | 72 |
| ,, D | | 208 | 168 | 180 | 184 | 179 | 182 | 182 |
| ,, H | | 209 | 168 | 168 | 182 | 178 | 180 | 180 |
| ,, J | | 118 | 160 | 168 | 176 | 174 | 176 | 178 |
| ,, M | | 79 | 148 | 154 | 163 | 168 | 170 | 172 |
| ,, S | | 92 | 108 | 104 | 98 | 92 | 88 | 86 |

WHEN DRAWING OFF.

| Time in minutes | — | — | — | 86 | — | — | — | 87 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 130 | 120 | 112 | 106 | 100 | 96 | 92 | 88 | 86 | 84 |
| ,, D | 208 | 208 | 207 | 207 | 207 | 207 | 208 | 208 | 208 | 209 |
| ,, H | 206 | 206 | 206 | 206 | 206 | 206 | 206 | 206 | 206 | 206 |
| ,, J | 200 | 200 | 198 | 198 | 192 | 164 | 152 | 146 | 142 | 140 |
| ,, M | 198 | 198 | 198 | 198 | 198 | 198 | 198 | 198 | 198 | 197 |
| ,, S | 196 | 200 | 198 | 198 | 197 | 188 | 182 | 180 | 178 | 178 |

| Time in minutes | — | 88 | — | — | — | 89 | — | — | — | 90 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 80 | 78 | 76 | 76 | 74 | 72 | 72 | 72 | 72 | 72 |
| ,, D | 209 | 210 | 210 | 211 | 210 | 210 | 210 | 209 | 208 | 208 |
| ,, H | 206 | 206 | 208 | 208 | 210 | 210 | 210 | 209 | 209 | 209 |
| ,, J | 136 | 136 | 136 | 136 | 128 | 132 | 128 | 128 | 122 | 118 |
| ,, M | 195 | 193 | 190 | 170 | 100 | 88 | 82 | 82 | 80 | 79 |
| ,, S | 176 | 176 | 176 | 166 | 105 | 104 | 100 | 98 | 96 | 92 |

## EXPERIMENT VII.

In this experiment, as will be seen by the drawing, Fig. 10, the flow-pipe was connected to the extreme top of the cylinder, where the bridge-piece was connected in the two previous cases. So far as the principle of circulation is concerned, the connections are similar to those employed in Experiments Nos. 6 and 6A; hence the result obtained during the heating process presents no new features.

The bridge-piece having been removed, it is interesting to observe the influence of this alteration on the result during the draw-off. The average temperature of the water drawn off is given with each result. On comparing the results thus summarised it will be found that when the system was connected, in the same way as the one now being studied, the highest average was obtained, which justifies the claim of a first place for this mode of connecting hot-water systems.

The best authorities on the question of "Domestic Hot Water Supply" are agreed that the flow-pipe should enter the cylinder about two-thirds up from the bottom. The rank and file of the trade have accepted this theory without question, and the majority of systems are fitted up with the flow-pipe entering the cylinder somewhere up the side.

So far as the writer is aware, it is not stated in any work on the subject why the flow-pipe should be so treated. Under ordinary conditions this method gives the very best results, but under certain other conditions it would be an improvement to connect the flow-pipe to the extreme top of the cylinder, as in the present instance.

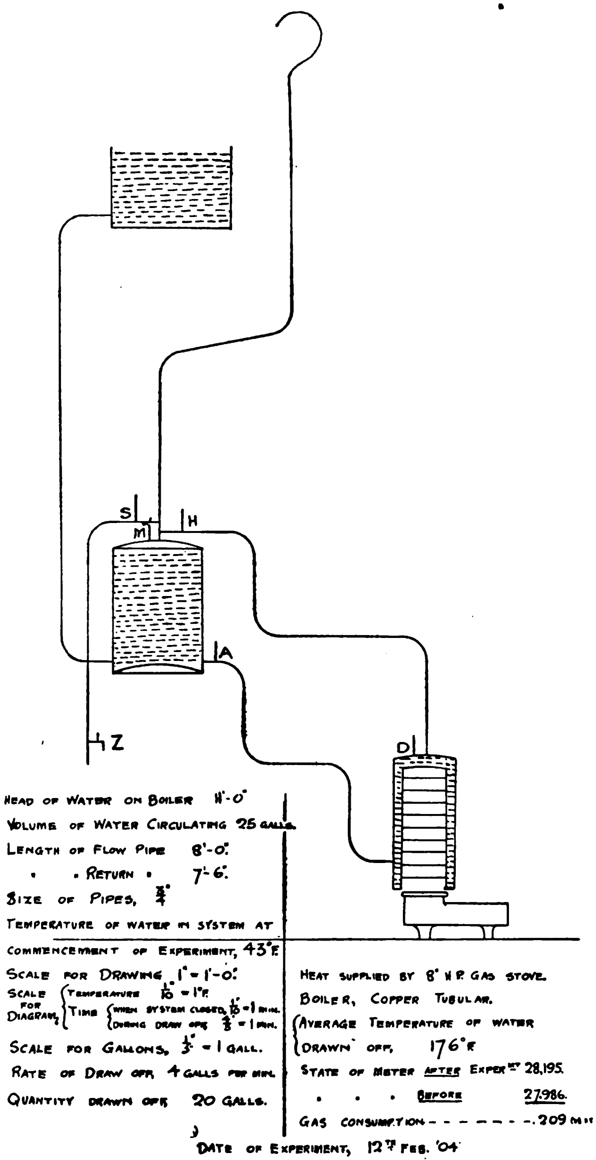
On looking at the curve M, Fig. 10A, which represents the temperature of the water at the top of the cylinder (during the heating process), one is struck with the fact that it occupies a position much nearer to H and D than that occupied by the corresponding thermometer in Experiment No. 5, when the flow-pipe entered the cylinder two-thirds up from the bottom.

This is what might be expected, for when the hot water enters at the top of the cylinder it remains concentrated, whereas in Experiment No. 5 it entered the cylinder at a lower level, and was diluted and chilled by passing through a column of colder water. Under certain circumstances this dilution or cooling would be no disadvantage, but under certain other conditions it would mean a serious loss of time in obtaining a supply of very hot water.

Take for example the case of a house where small quantities of hot water are required immediately the fire is lighted. If the flow-pipe enters the cylinder at a low level, hot water cannot be drawn until the water in the upper portion of the cylinder becomes heated; whereas if the flow-pipe enters the cylinder at the extreme top and the branch be taken off the expansion, as in the case of this experiment (or the branch may be taken direct off the cylinder if desired), hot water can be drawn off almost immediately before any mixing (*i.e.*, cooling) takes place.

As already stated, so far as heating the water is concerned there is very little to choose between this method of connecting the flow-pipe and that of connecting it to the cylinder somewhere up the side; but on looking at the curves representing the draw-off (Fig. 10A), it is seen that the system adopted in Experiment No. 7 has a decided advantage over the other.

What happens when hot water is delivered at the top of a cylinder? Does it mix with the cold water contained in the cylinder, as, for example, ink would mix? or does it float on the top, as oil would do? For the answer one has only to refer to the curves. At the commencement of the experiment all the thermometers registered a temperature of 43 degrees. When heat was applied D rose rapidly, closely followed by H, and M will be noticed a little lower. But A had not shown any rise in temperature at the end of 35 minutes, which demonstrates that



HEAD OF WATER ON BOILER 11'-0"
VOLUME OF WATER CIRCULATING 25 GALLS.
LENGTH OF FLOW PIPE 8'-0".
" " RETURN " 7'-6".
SIZE OF PIPES, 3/4"
TEMPERATURE OF WATER IN SYSTEM AT COMMENCEMENT OF EXPERIMENT, 43°F.
SCALE FOR DRAWING 1" = 1'-0".
SCALE FOR DIAGRAM, TEMPERATURE 1/10" = 1°F. TIME WHEN SYSTEM CLOSED, 1/16" = 1 MIN. DURING DRAW OFF 3/8" = 1 MIN.
SCALE FOR GALLONS, 1/3" = 1 GALL.
RATE OF DRAW OFF, 4 GALLS PER MIN.
QUANTITY DRAWN OFF 20 GALLS.

HEAT SUPPLIED BY 8" H.P. GAS STOVE.
BOILER, COPPER TUBULAR.
AVERAGE TEMPERATURE OF WATER DRAWN OFF, 176°F.
STATE OF METER AFTER EXPERMT 28,195.
" " " BEFORE 27,986.
GAS CONSUMPTION - - - - - - - - .209 Mft

DATE OF EXPERIMENT, 12TH FEB. '04

FIG. 10 (EXPERIMENT NO. 7).—SHOWING ARRANGEMENT OF APPARATUS.

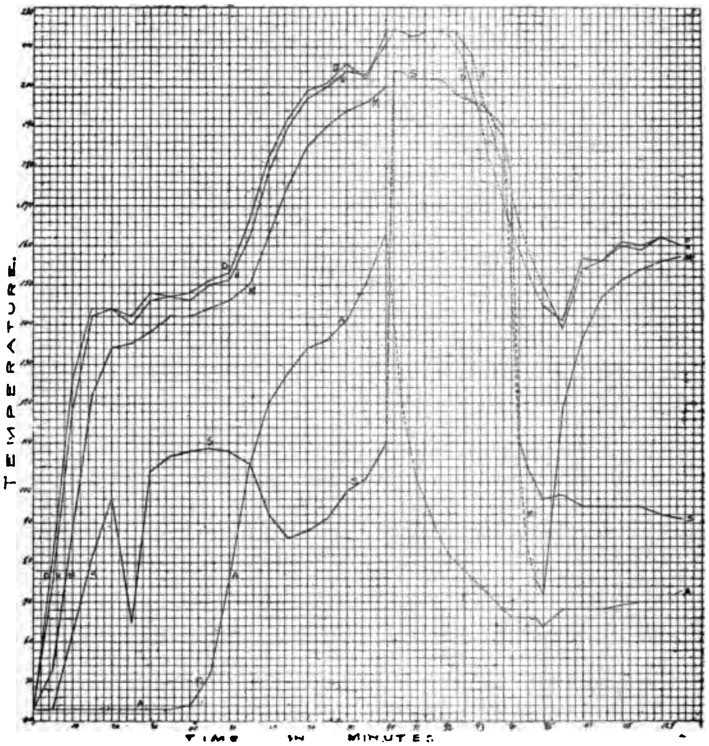


FIG. 10A (EXPERIMENT NO. 7).—DIAGRAM SHOWING RESULTS PLOTTED.

none of the hot water which entered the cylinder 35 minutes previously had reached the point where A was fitted on the return-pipe.

If any mixing had taken place the mixed water would have affected thermometer A before the end of 35 minutes; and it is interesting to notice that when A began to rise it did so rapidly, in an almost parallel line to M; which proves that A travelled in the footsteps of M so many minutes later, showing that the water was travelling in what might be described as consecutive layers, or Indian file, to use a military term. These curves teach this, if nothing else: that if hot water be delivered on the top of cold water, the hot water remains on the top the same as any other body having less specific gravity.

At the end of ninety minutes twenty gallons of water were drawn off at the rate of four gallons per minute, and it will be noticed from the plotted result that the water drawn off (as represented by the curve S) was at a higher temperature than the water at the top of the cylinder. Although the difference was very slight the fact serves to prove that a portion of the water drawn off was drawn from the boiler, the flow-pipe fulfilling the same function as the bridge-piece had done in the two previous experiments. From this it would appear that in a system connected on this principle it is possible to draw off, not alone the hot water contained in the cylinder at its maximum temperature, but also to empty, or partially empty, the boiler of hot water. Whether this be an advantage or otherwise is a question which, for the present, must be deferred.

It has been argued more than once that if the pipes be connected in this way cold water will be drawn from the boiler before the hot water in the cylinder has been exhausted. Such did not happen in this experiment, and it is questionable whether it would happen under ordinary circumstances; for on looking at the curves in the present case, it will be seen when the twentieth gallon was being drawn off the water was leaving the boiler at 145 degrees; that at the top of the cylinder at the same instant being only 72 degrees; while water was being drawn off at the intermediate temperature of 96 degrees—24 degrees hotter than the water at the top of the cylinder.

This makes it clear that, instead of drawing cold water through the boiler before the hot water in the cylinder had been exhausted, what really did happen was that, after the supply of hot water in the cylinder had been exhausted, the boiler was still supplying a quantity of hot water which, mixing with the colder water from the top of the cylinder, gave an intermediate mixture, as represented by the dotted lines.

This point will be still further discussed when treating the results of subsequent experiments; but it may here be said that the size and length of the circulating pipes, as well as the size, length and position of the branch pipes, are important factors which must be taken into account when fitting up a system on the above principle.

Heat was continued for 35 minutes after the draw-off, and the same thing occurred as before, viz., the water at the different temperatures found their respective levels.

### TABULATED RESULT OF EXPERIMENT NO. 7.

WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 44 | 52 |
| ,, D | 43 | 82 | 126 | 144 | 144 | 142 | 148 | 147 | 148 | 151 |
| ,, H | 43 | 76 | 119 | 142 | 144 | 140 | 146 | 147 | 146 | 150 |
| ,, M | 43 | 53 | 88 | 122 | 134 | 135 | 138 | 142 | 142 | 144 |
| ,, S | 43 | 43 | 62 | 82 | 96 | 65 | 103 | 107 | 108 | 109 |

| Time in minutes | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 76 | 104 | 120 | 128 | 134 | 136 | 141 | 150 | 163 | Draw-off |
| ,, D | 153 | 166 | 182 | 192 | 199 | 201 | 206 | 202 | 214 | |
| ,, H | 151 | 162 | 179 | 190 | 197 | 200 | 204 | 203 | 211 | |
| ,, M | 146 | 150 | 163 | 175 | 185 | 190 | 194 | 196 | 200 | |
| ,, S | 108 | 105 | 92 | 86 | 88 | 91 | 98 | 101 | 110 | |

| Time in minutes | 95 | 100 | 105 | 110 | 115 | 120 | 125 | 130 |
|---|---|---|---|---|---|---|---|---|
| Thermometer A | 64 | 68 | 68 | 68 | 69 | 70 | 70 | 73 |
| ,, D | 145 | 141 | 157 | 156 | 161 | 160 | 162 | 160 |
| ,, H | 150 | 139 | 154 | 156 | 160 | 159 | 162 | 160 |
| ,, M | 72 | 119 | 136 | 147 | 151 | 154 | 156 | 157 |
| ,, S | 96 | 97 | 94 | 94 | 94 | 94 | 92 | 91 |

WHEN DRAWING OFF.

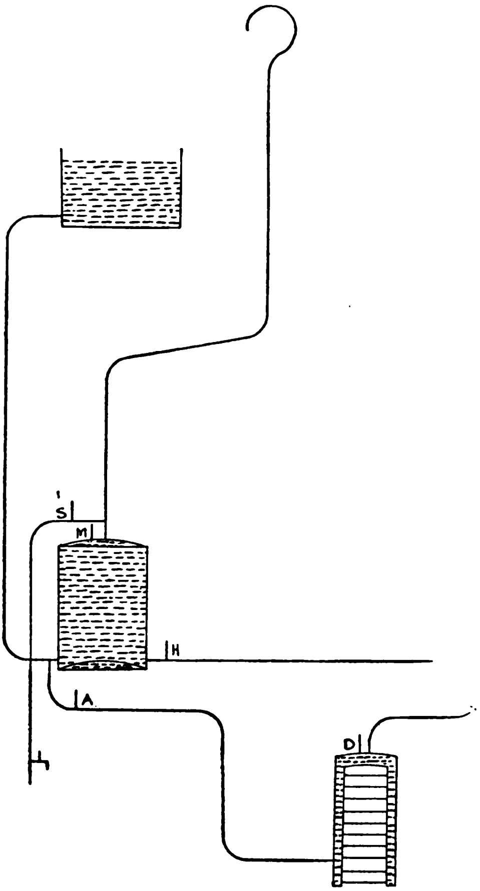
| Time in minutes | — | — | — | 91 | — | — | — | 92 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 140 | 120 | 110 | 100 | 96 | 90 | 86 | 82 | 80 | 78 |
| ,, D | 214 | 214 | 214 | 214 | 214 | 214 | 214 | 213 | 210 | 207 |
| ,, H | 214 | 214 | 213 | 213 | 214 | 214 | 214 | 214 | 214 | 211 |
| ,, M | 200 | 200 | 200 | 200 | 200 | 200 | 198 | 198 | 198 | 197 |
| ,, S | 204 | 204 | 202 | 202 | 202 | 202 | 202 | 200 | 198 | 198 |

| Time in minutes | — | 93 | — | — | — | 94 | — | — | — | 95 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 76 | 74 | 72 | 70 | 68 | 66 | 66 | 66 | 66 | 64 |
| ,, D | 200 | 192 | 183 | 178 | 171 | 164 | 159 | 154 | 149 | 145 |
| ,, H | 208 | 200 | 192 | 186 | 180 | 173 | 166 | 160 | 155 | 150 |
| ,, M | 197 | 194 | 194 | 192 | 190 | 150 | 104 | 84 | 76 | 72 |
| ,, S | 196 | 196 | 194 | 190 | 188 | 178 | 110 | 104 | 100 | 96 |

## EXPERIMENT XII.

In order to classify the experiments, it will at this stage be convenient to pass over Nos. 8, 9, 10, 11, which deal with dips, and take up Experiment No. 12, which treats of circulation and draw-off.

On referring to Fig. 11, it will be seen that in this experiment the flow-pipe was connected to the bottom of the cylinder,



HEAD OF WATER ON BOILER. 11'-0"
LENGTH OF FLOW PIPE, 8'-0"
· · RETURN · 7'-6"
SIZE OF PIPES $\frac{3}{4}$"
VOLUME OF WATER CIRCULATING, 25 GALLS.
TEMPERATURE OF WATER AT COMMENCEMENT OF EXPERIMENT 47°F
AMOUNT OF WATER DRAWN OFF,
1ST DRAW OFF 20 GALLONS.
2ND · · 10 ·
RATE OF DRAW OFF. 4 GALLS. PER MIN.
AVERAGE TEMPERATURE OF 1ST DRAW OFF 157°F

SCALE FOR DRAWING 1" = 1'-0"
SCALE FOR DIAGRAM. TEMPERATURE $\frac{1}{10}$" = 1°F
SCALE FOR DIAGRAM. TIME WHEN SYSTEM CIRCULATING $\frac{1}{10}$" = 1 MIN.
SCALE FOR DIAGRAM. TIME DURING DRAW OFF $\frac{4}{5}$" = 1 MIN.
SCALE FOR GALLONS $\frac{1}{5}$" = 1 GALL.
HEAT SUPPLIED BY 8" HP GAS STOVE.
STATE OF METER AFTER EXPERT. 29,275
· · · BEFORE · 29,063
GAS CONSUMPTION ....... 212 C.FEET
DATE OF EXPERIMENT, 23RD FEB. '04.

FIG. 11 (EXPERIMENT 12).—DRAWING SHOWING ARRANGEMENT OF PIPES.

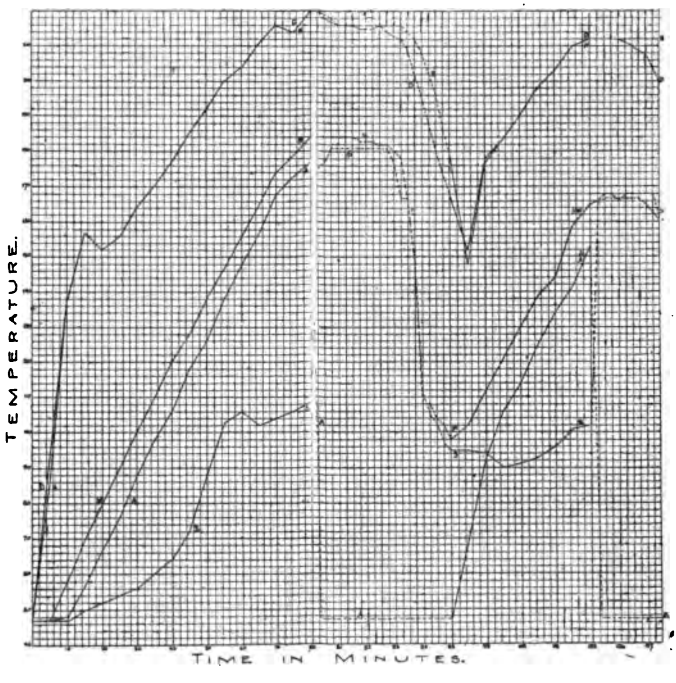


FIG. 11A (EXPERIMENT 12).—DIAGRAM SHOWING RESULTS PLOTTED.

and that the return-pipe was connected to the cold supply immediately before it entered the cylinder; this method of connecting the return-pipe being adopted for the sake of convenience. The branch was taken off the expansion-pipe immediately above the cylinder. The lengths of the various pipes were the same as in previous experiments.

When heat was first applied the thermometer at D rose rapidly, closely followed by the one at H, as in previous cases. Thermometer M did not rise so quickly, but A commenced to rise within ten minutes, and at the end of 15 minutes it registered 57 degrees, being a rise of 10 degrees in that time; whereas in the previous experiments no change of temperature at this point was registered for a period of about thirty minutes (on an average).

On looking at the plotted results it will be seen that curves A and M are more uniform than the corresponding curves in the experiments already considered, the curves representing the rise of temperature at these points being almost straight lines. It will be noticed A occupies a position very much closer to M than in the other results, indicating that the water in the cylinder was at a more uniform temperature with this arrangement of pipes.

The difference in temperature between the water at the top of the cylinder and that at the top of the boiler, as represented by curves D and M, is very noticeable, and shows that there would be considerable delay in obtaining a supply of hot water from the top of the cylinder, as the whole volume of water in the cylinder must be heated before any hot water can be drawn off. This must be considered a very serious disadvantage, for a ready supply of hot water is the chief feature of a perfect hot water system. Yet, as we all know, many hot water systems are fitted up with the flow-pipe entering at the bottom of the cylinder. Such a system will do very well if a speedy supply of hot water is of no object, but where hot water is required soon after the fire is lighted this method cannot give satisfaction.

After heat had been applied 80 minutes, 20 gallons of water were drawn off at the rate of 4 gallons per minute. As the cold supply was connected to the return-pipe, the mixing that usually goes on in the cylinder during the time water is being drawn off was considerably reduced. The effect of this will be seen on referring to the curves representing the draw-off. It will be observed, in the case of the first draw-off, that 14 gallons had been drawn off before the mixing extended to the top of the cylinder. In the case of the second draw-off, 10 gallons were obtained at almost the same temperature, as shown by the dotted curves on the extreme right of the diagram, Fig. 11 A.

It will also be noticed that the water was not drawn off at the same high temperature as when the flow-pipe entered the cylinder near the top, the hottest water drawn off being 181 degs., as compared with 204 degs. in the case of Experiment No. 7; but the average temperature of the water drawn off compares more favourably (see Fig. 11).

When 20 gallons had been drawn off the system was allowed to heat up again, after which 10 gallons more were drawn off. It will be seen by the plotted result that the same thing happened in the two periods of heating and draw-off.

It is unnecessary to dwell at length on this result, the chief feature of which is the comparatively low temperature of the water at the top of the cylinder, compared with that of the water leaving the boiler, and with the temperature of the water at this point in other experiments; but the more uniform temperature of the water in the cylinder somewhat counterbalances this disadvantage.

## TABULATED RESULT OF EXPERIMENT NO. 12.

### WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 47 | 47 | 48 | 57 | 67 | 76 | 88 | 98 | 106 | 118 |
| ,, D | 47 | 94 | 137 | 157 | 152 | 156 | 169 | 170 | 177 | 185 |
| ,, H | 47 | 88 | 137 | 157 | 152 | 156 | 169 | 170 | 177 | 185 |
| ,, M | 47 | 47 | 58 | 70 | 80 | 90 | 100 | 110 | 120 | 128 |
| ,, S | 47 | 47 | 47 | 50 | 52 | 54 | 56 | 60 | 64 | 72 |

| Time in minutes | 50 | 55 | 60 | 65 | 70 | 75 | 80 | | 85 | 90 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 126 | 138 | 148 | 157 | 168 | 173 | 177 | Draw-off | 47 | 70 |
| ,, D | 192 | 200 | 204 | 211 | 216 | 214 | 220 | | 168 | 152 |
| ,, H | 192 | 200 | 204 | 211 | 216 | 214 | 220 | | 180 | 148 |
| ,, M | 138 | 147 | 156 | 165 | 174 | 179 | 184 | | 98 | 102 |
| S | 88 | 103 | 106 | 102 | 104 | 106 | 109 | | 95 | 95 |

| Time in minutes | 95 | 100 | 105 | 110 | 115 | 120 | 125 | |
|---|---|---|---|---|---|---|---|---|
| Thermometer A | 93 | 106 | 114 | 125 | 134 | 151 | 163 | Draw-off |
| ,, D | 178 | 183 | 190 | 198 | 203 | 210 | 212 | |
| ,, H | 177 | 183 | 190 | 198 | 203 | 210 | 212 | |
| ,, M | 112 | 121 | 130 | 139 | 144 | 159 | 165 | |
| ,, S | 94 | 90 | 91 | 93 | 96 | 101 | 102 | |

### WHEN DRAWING OFF.—(FIRST.)

| Time in minutes | — | — | — | 81 | — | — | — | 82 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 80 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 |
| ,, D | 220 | 219 | 218 | 216 | 216 | 216 | 215 | 215 | 215 | 216 |
| ,, H | 220 | 218 | 217 | 216 | 216 | 216 | 216 | 216 | 216 | 216 |
| ,, M | 184 | 184 | 184 | 184 | 184 | 184 | 183 | 183 | 183 | 182 |
| ,, S | 175 | 177 | 181 | 181 | 181 | 181 | 181 | 181 | 181 | 181 |

| Time in minutes | — | 83 | — | — | — | 84 | — | — | — | 85 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 |
| ,, D | 214 | 213 | 212 | 209 | 202 | 195 | 188 | 180 | 174 | 168 |
| ,, H | 216 | 216 | 216 | 214 | 212 | 208 | 202 | 196 | 186 | 180 |
| ,, M | 182 | 180 | 178 | 165 | 148 | 108 | 108 | 104 | 102 | 98 |
| ,, S | 181 | 177 | 167 | 167 | 147 | 111 | 105 | 103 | 97 | 95 |

(SECOND.)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time in minutes | — | — | — | 126 | — | — | — | 127 | — | — |
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 80 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 |
| ,, D | 212 | 212 | 212 | 212 | 211 | 210 | 209 | 208 | 204 | 200 |
| ,, H | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 |
| ,, M | 166 | 168 | 168 | 166 | 168 | 168 | 168 | 168 | 168 | 162 |
| ,, S | 165 | 167 | 167 | 167 | 167 | 167 | 167 | 165 | 163 | 161 |

## EXPERIMENT XIII.

If the reader will turn to Fig. 12, which shows the arrangement of the pipes in Experiment No. 13, he will see that the circulating pipes were connected in the same way as in Experiment No. 5, but it will be noticed that the branch-pipe was taken off the flow or hot water circulating-pipe.

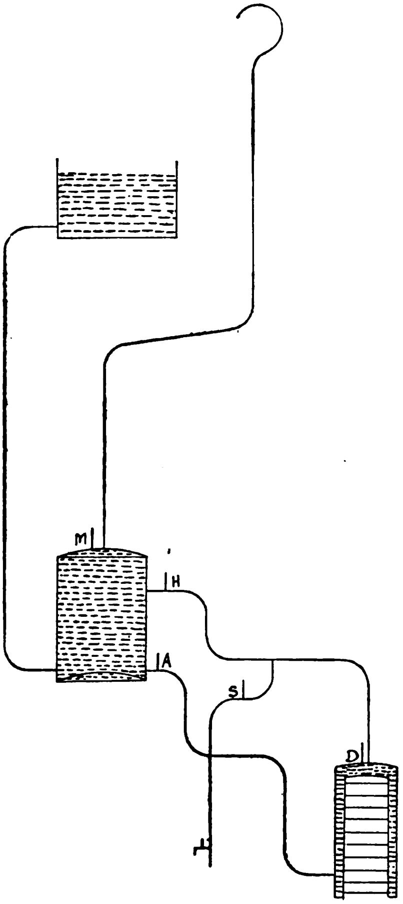
This method of connecting the branch-pipe will be recognised as one adopted when some of us were apprentices, and, indeed, the custom of taking branches off the flow-pipes has not passed away with our youth, for at the present day many installations are treated in this way.

The principal reason why this method of connecting hot water systems, or, rather, taking off branches for hot water supplies, became unpopular was (if the writer remembers aright) the trouble and annoyance caused by the pipes bursting, due to the sudden change of temperature and consequent unequal expansion and contraction of the pipes. But to the writer's mind there is a much stronger objection, proved by the results of Experiment No. 13, to the custom of taking branches off the circulating-pipe for the supply of *certain fittings* with hot water. The term *certain fittings* is used lest the author should be thought to condemn wholesale the principle of taking branches off the flow-pipe for any purpose.

So far as the results obtained during the heating periods are concerned, no new feature could be expected, and it will be seen that the curves, Fig. 12 A, with which it is hoped the reader is by this time familiar, are similar to those previously obtained in experiments conducted on systems connected in the same way.

The tabulated results show that at the commencement of the draw-off the water was leaving the boiler at 220 degs.; the water at the top of the cylinder stood at 207 degs.; and the water passing through the return-pipe, at the point where thermometer A was fitted, was 194 degs. The temperature at the latter point was higher in the present case than in any other experiments, therefore the conditions were favourable for a good supply of hot water being drawn off.

Although immediately before the tap was opened thermometer S (on the branch) stood at 206 degrees, the instant it was opened this thermometer jumped up to 216 degrees (4 degs. above



HEAD OF WATER ON BOILER 11'-0"
LENGTH OF FLOW PIPE 8'-0"
" " RETURN " 7'-6"
SIZE OF PIPES. $\frac{3}{4}$"
VOLUME OF WATER CIRCULATING, 25 GALLS.
{TEMPERATURE OF WATER AT COMMENCEMENT OF EXPERIMENT, 45°
{AMOUNT OF WATER DRAWN OFF,
1ST DRAW OFF, 20 GALLONS.
2ND " " 10 "
SCALE FOR GALLONS, $\frac{1}{5}$" = 1 GALLON.

SCALE FOR DRAWING, 1" = 1'-0"
SCALE FOR DIAGRAM, TEMPERATURE, $\frac{1}{10}$" = 1°F.
TIME, WHEN SYSTEM CIRCULATING, $\frac{1}{10}$" = 1 MIN.
DURING DRAW OFF, $\frac{4}{5}$" = 1 MIN.
AVERAGE TEMPERATURE OF 1ST DRAW OFF, 168°F.
RATE OF DRAW OFF, 4 GALLS. PER MIN.
HEAT SUPPLIED BY 8" H.P. GAS STOVE.
STATE OF METER AFTER EXPERT. 29,485.
" " " BEFORE " 29,275.
GAS CONSUMPTION ------ 210 c.
DATE OF EXPERIMENT, 24TH FEB. '04.

FIG. 12 (EXPERIMENT 13).—DRAWING SHOWING ARRANGEMENT OF PIPES.

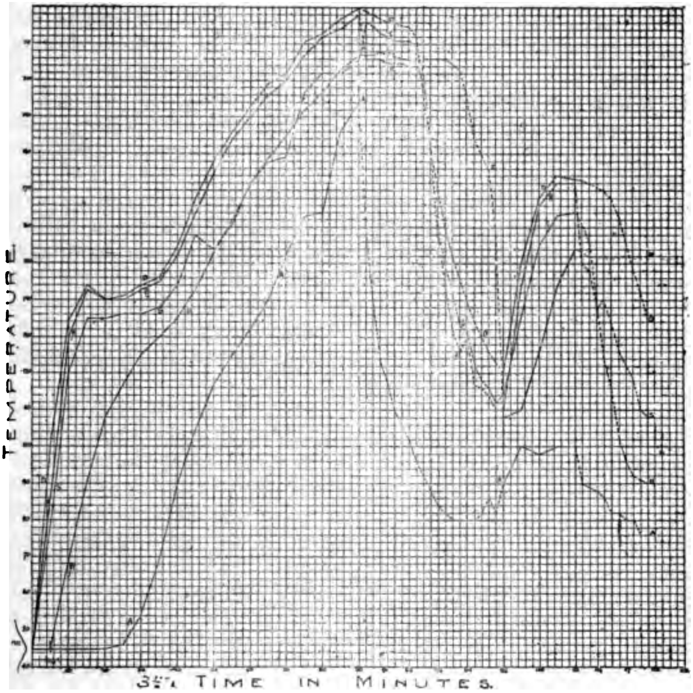


FIG. 12 A (EXPERIMENT 13).—DIAGRAM SHOWING RESULTS PLOTTED.

boiling point), and the first 3 gallons issued from the cock in the form of steam. The water in the system being under pressure was heated above 212 degrees, but as on leaving the tap it was only subjected to atmospheric pressure, became converted into steam. It is well known that water under pressure may be raised to a certain temperature above boiling point (depending on the pressure), but on being liberated it is instantly converted into steam. This suggests what would happen if a kitchen boiler containing water so heated should burst. The water contained in the boiler occupies a comparatively small space in the liquid state, but when heated to a high temperature, if suddenly liberated it would be instantly converted into the very expansive gas known as "steam," bringing about consequences too terrible to contemplate. Yet hundreds, nay, thousands of houses have hot water systems in connection with which no provisions are made to guard against such an occurrence.

To dwell on this point would be departing from the subject under consideration, therefore the reader must again turn his attention to the dotted curves which represent the changes of temperature at the different points during the period of the draw-off. It has already been pointed out that the first few gallons drawn off were at a very high temperature; in fact, the first 8 gallons were at an average temperature of 212 degrees, but after this thermometer S fell very quickly.

On comparing the temperatures registered by the different thermometers at the end of, say, the twelfth gallon, it will be found that the hottest water in the system was at the top of the cylinder, for at this particular period D registered 160 degrees, H 150 degrees; S, which indicated the temperature of the water that was being drawn off also stood at 150 degrees, whilst M at the same moment recorded 206 degrees. In other words the water issuing from the tap was 56 degrees colder than the water at the top of the cylinder, showing that the hot water was stored at the top of the cylinder and could not be drawn off. In scores of cases throughout the kingdom hot water is stored in the cylinder or tank and cannot be drawn off; in fact the writer knows of several systems now being fitted up where the branch is taken off the flow-pipe below the level of the cylinder.

The plumber often wonders why people complain that they cannot get enough hot water to give a warm bath. The system is fitted up in the same way as dozens of others he has done, so the boiler must be at fault. Being anxious to set matters right and keep his client in *hot water* (no pun intended) whilst bringing grist to his own mill, he suggests a larger boiler and new range. The *doctor* having ordered warm baths for some of the children, hot water must be had at any price, so the owner has no option but submit with the best grace possible to the *plumber's* prescription. The new range and larger boiler are accordingly fitted up. These improvements, coupled with plenty of coal (the latter in particular), effect a cure, and the plumber is the hero of the hour. But the hard fact remains, that if the flow-pipe be connected to the cylinder and the branch taken off the flow-pipe below the level of the cylinder (as is always the case), hot water will still be stored at the top of the cylinder, to remain there in obedience to a natural law, and cannot be drawn off. The boiler and excessive firing is capable of heating the water as fast as it is drawn through the system, when a tap is open; consequently the cause of complaint has apparently been removed.

In order to confirm the result of the first draw-off the application of heat was continued, and it will be noticed from the solid curves on the right of the first series of dotted curves how very quickly the water at the different temperatures wheeled into line.

At the expiration of 115 minutes from the commencement of the experiment (20 minutes after the first draw-off) the tap was again opened, and 10 gallons were drawn off at the rate of 4 gallons per minute. The result of this second draw-off is shown by the second series of dotted curves on the extreme right of the diagram, Fig. 12 A.

It will be seen that the temperature of the water at the beginning of the second draw-off was not so high as at the commencement of the first draw-off, the hottest water being only 173 degrees, whilst at the commencement of the first draw-off the water was leaving the boiler at 220 degrees, showing that the draw-offs were conducted under slightly different conditions. Yet notwithstanding this fact the same thing happened in each case—cold water being drawn off while the hot water remained at the top of the cylinder.

These results convince one of the defects of this system. The dotted curves which represent the travel of the thermometers during the second draw-off show that M, which represents the temperature of the water at the tap of the cylinder, is a horizontal line, denoting that there was no change of temperature at that point during the time the tap was open; whilst S is on the down ward course throughout the draw-off, proving that the hot water remained at the top whilst the colder water was drawn from underneath it in the most direct route. If the reader will turn to the tabulated results he will see that at the end of the tenth gallon M stood at 152 degrees and S at 108 degrees, showing that the water drawn off was 44 degrees colder than the water at the top of the cylinder.

There are many other points in this and the other recorded results which are well worthy of the reader's attention, although lack of space prevents their consideration in these articles. The reader will, however, have no difficulty in studying the tabulated and plotted results, and making many deductions that may prove useful to him in his everyday practice.

## TABULATED RESULT OF EXPERIMENT NO. 13.

### WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 45 | 45 | 45 | 45 | 45 | 46 | 54 | 70 | 90 | 105 |
| ,, D | 45 | 102 | 134 | 144 | 140 | 141 | 144 | 146 | 155 | 168 |
| ,, H | 45 | 86 | 130 | 143 | 140 | 140 | 143 | 145 | 152 | 164 |
| ,, M | 45 | 45 | 68 | 90 | 108 | 117 | 125 | 130 | 135 | 143 |
| ,, S | 45 | 80 | 120 | 135 | 135 | 136 | 136 | 138 | 144 | 158 |

| Time in minutes | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 117 | 125 | 132 | 140 | 152 | 163 | 164 | 186 | 194 | Draw-off |
| ,, D | 178 | 186 | 193 | 199 | 202 | 211 | 213 | 217 | 220 | |
| ,, H | 175 | 184 | 190 | 196 | 200 | 207 | 212 | 214 | 218 | |
| ,, M | 153 | 162 | 172 | 179 | 185 | 192 | 197 | 203 | 207 | |
| ,, S | 154 | 161 | 172 | 178 | 179 | 197 | 202 | 202 | 206 | |

| Time in minutes | 95 | 100 | 105 | 110 | 115 | |
|---|---|---|---|---|---|---|
| Thermometer A | 90 | 100 | 98 | 100 | 100 | Draw-off |
| ,, D | 120 | 150 | 168 | 174 | 173 | |
| ,, H | 110 | 144 | 166 | 172 | 172 | |
| ,, M | 108 | 110 | 126 | 144 | 154 | |
| ,, S | 114 | 136 | 155 | 163 | 164 | |

### WHEN DRAWING OFF.—(FIRST.)

| Time in minutes | — | — | — | 91 | — | — | — | 92 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 160 | 140 | 124 | 118. | 110 | 106 | 102 | 96 | 92 | 88 |
| ,, D | 219 | 218 | 217 | 216 | 216 | 215 | 215 | 212 | 196 | 182 |
| ,, H | 206 | 206 | 206 | 205 | 205 | 205 | 204 | 204 | 200 | 184 |
| ,, M | 207 | 207 | 208 | 207 | 207 | 206 | 206 | 206 | 206 | 206 |
| ,, S | 216 | 215 | 213 | 212 | 211 | 211 | 211 | 210 | 202 | 184 |

| Time in minutes | — | 93 | — | — | — | 94 | — | — | — | 95 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 84 | 82 | 80 | 80 | 80 | 80 | 82 | 86 | 82 | 90 |
| ,, D | 170 | 160 | 152 | 146 | 140 | 134 | 130 | 126 | 123 | 120 |
| ,, H | 158 | 150 | 142 | 133 | 132 | 122 | 118 | 116 | 110 | 110 |
| ,, M | 206 | 206 | 205 | 203 | 196 | 184 | 180 | 176 | 160 | 108 |
| ,, S | 158 | 150 | 142 | 133 | 132 | 122 | 118 | 116 | 112 | 114 |

### (SECOND.)

| Time in minutes | — | — | — | 116 | — | — | — | 117 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 90 | 89 | 88 | 86 | 82 | 82 | 80 | 80 | 76 | 76 |
| ,, D | 173 | 172 | 171 | 170 | 168 | 163 | 156 | 149 | 142 | 135 |
| ,, H | 150 | 148 | 138 | 124 | 116 | 102 | 96 | 92 | 91 | 90 |
| ,, M | 153 | 152 | 152 | 152 | 152 | 152 | 152 | 152 | 152 | 152 |
| ,, S | 161 | 156 | 138 | 140 | 134 | 126 | 122 | 119 | 110 | 108 |

## EXPERIMENT XV.

Before dealing with Experiment No. 15 (which is the next that treats of draw-off), it will be well to study the arrangement of the pipes in Experiment 13, Fig. 12. It will be seen the flow-pipe entered the cylinder 8 in. from the top, and that the branch was taken off this pipe a few inches above the level of the bottom of the cylinder. Thus the head pressure at the point where the branch was taken off, and at the point where the return was connected to the cylinder, was greater than at the point where the flow-pipe entered the cylinder.

Having noted the above facts we now turn our attention to the arrangements of the pipes in Experiment 15, Fig. 13. From the drawing it will be seen that they differ from those of Experiment 13 in having the flow-pipe connected to the extreme top of the cylinder, as in Experiment 7, the branch being taken off at the same level, and in the same position as in Experiment 13. In every other respect the apparatus was exactly similar in these two cases.

As the results of experiments conducted on systems connected in the same way have already been discussed, it is unnecessary to review the results obtained during the heating process in the present case, but it is well again to note the similarity between the curves, showing the uniformity of results obtained from systems connected on the same principle.

A thermometer being fitted at the point O, Fig. 13, the result is represented by six curves. The additional curve need not be studied at present, as it will be referred to when treating of the rate of circulation.

The chief defect of the previous system (Experiment 13) was that the hot water remained at the top of the cylinder and could not be drawn off. It might appear at first sight that this defect could be remedied by connecting the flow to the extreme top of the cylinder, thereby providing an avenue of escape for the water imprisoned at the top of the cylinder; but while such a change is a remedy for this defect, it introduces another, for it is not alone the question of unequal specific gravity, but also the question of unequal head-pressure that has to be taken into account.

As will be seen from Fig. 13, when the tap is open the water may travel to the branch in two directions (1) by way of the return-pipe and through the boiler—the more circuitous route; or (2) it may take the more direct route *up* through the cylinder and through the short leg of the flow-pipe. The fact that the major portion of the water drawn off travelled by way of the return-pipe through the boiler was clearly proved by the experiment, the results of which are shown by the dotted curves, Fig. 13 A, which represent the period of the draw. If the reader will refer to the tabulated result, and, take, for instance, the readings of the thermometers at the end of the tenth gallon, as follows:—D 125, H 198, S 126, it will be seen that D and S are at practically the same temperature, while H is very much higher; which proves that the cold water entering at the bottom of the cylinder rushed down the return-pipe through the boiler to the branch. The reason the water travelled in this direction was due to the fact that the entrance to the return-pipe and the point where the branch-pipe

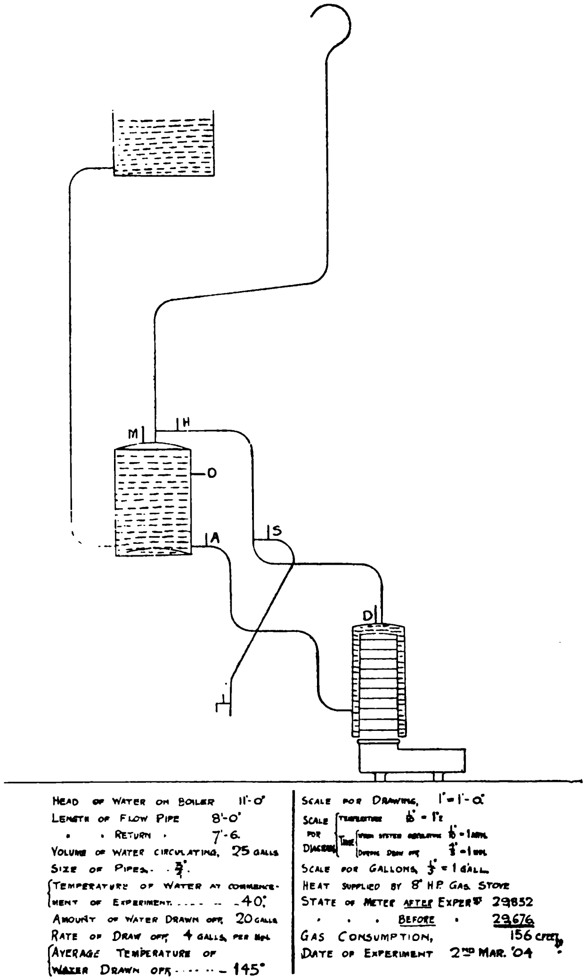

M
H
O
A
S
D
Head of Water on Boiler 11'-0"
Length of Flow Pipe 8'-0"
" " Return " 7'-6.
Volume of Water circulating, 25 galls
Size of Pipes. - ¾".
Temperature of Water at commencement of Experiment. ---- -- -40°.
Amount of Water Drawn off, 20 galls
Rate of Draw off, 4 galls, per min.
Average Temperature of Water Drawn off ---- -- - 145°
Scale for Drawing, 1" = 1'-0"
Scale for Diagram Temperature 1/10" = 1°F
Time When system circulating 1/10" = 1 min.
During Draw off 1/4" = 1 min.
Scale for Gallons, 1/3" = 1 Gall.
Heat supplied by 8" H.P. Gas Stove
State of Meter after Experiment 29852
" " " Before " 29676
Gas Consumption, 156 cubic ft
Date of Experiment 2nd Mar. '04

FIG. 13 (EXPERIMENT 15).—DRAWING SHOWING ARRANGEMENT OF PIPES.

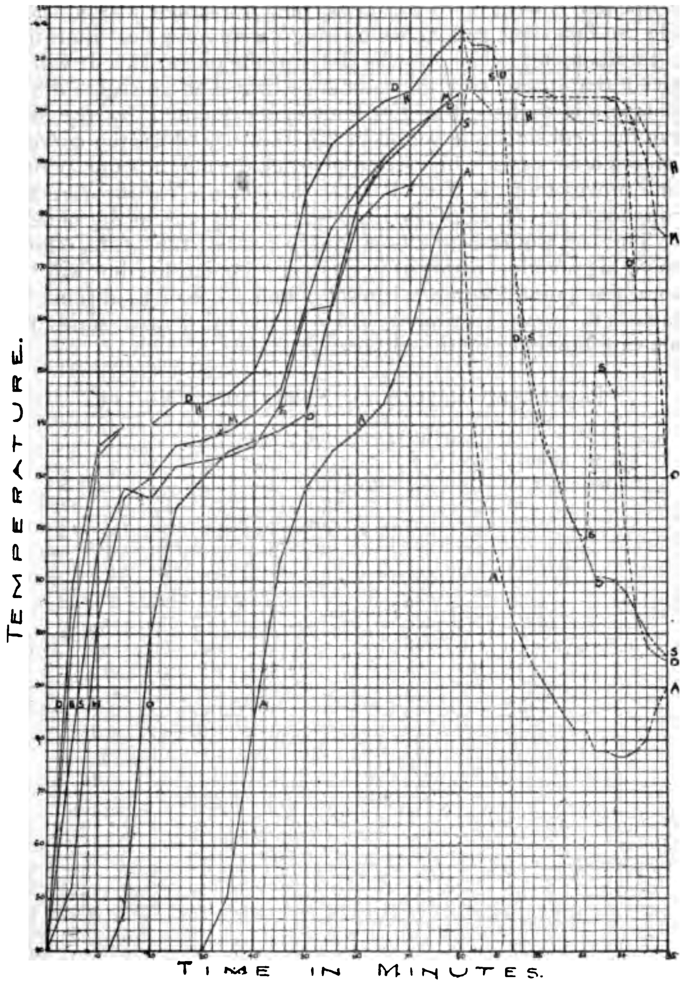


FIG. 13A (EXPERIMENT 15).—DIAGRAM SHOWING RESULTS PLOTTED.

was taken off was subjected to greater head pressure than the entrance to the flow-pipe at the top of the cylinder.

On referring to the curves it will be seen that when the tap was opened, S went up to 212 degs., and remained at that point while the first three gallons were being drawn off; but after that, this thermometer fell rapidly, as did also the one at D. It will be noticed that these two thermometers travelled in each other's footsteps, and that the travel of both is represented by the same curve for a considerable period of the draw-off, whilst the curve of H shows a very much higher temperature during the same period; which proves that the flow of water was mainly in one direction throughout the period of the draw-off, *viz.*, by way of the boiler.

This fact would bear closer study; but lest the writer should involve his practical mates in numerical calculations he will not labour the point further at present, but proceed to discuss the results of the next experiment, which is the third of a series that deals with branches off the circulating-pipe.

## TABULATED RESULT OF EXPERIMENT NO. 15.

WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 50 | 83 |
| ,, D | 40 | 110 | 136 | 140 | 140 | 144 | 144 | 146 | 150 |
| ,, H | 40 | 102 | 134 | 140 | 140 | 144 | 144 | 146 | 150 |
| ,, M | 40 | 52 | 103 | 126 | 130 | 136 | 137 | 139 | 142 |
| ,, O | 40 | 40 | 40 | 47 | 100 | 124 | 130 | 135 | 137 |
| ,, S | 40 | 79 | 116 | 128 | 126 | 132 | 133 | 134 | 136 |

| Time in minutes | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 114 | 128 | 135 | 139 | 144 | 157 | 176 | 188 | Draw-off. |
| ,, D | 162 | 184 | 194 | 198 | 202 | 204 | 211 | 216 | |
| ,, H | 162 | 184 | 194 | 198 | 202 | 204 | 211 | 216 | |
| ,, M | 147 | 163 | 178 | 185 | 191 | 196 | 200 | 204 | |
| ,, O | 139 | 142 | 164 | 182 | 190 | 195 | 200 | 204 | |
| ,, S | 144 | 162 | 163 | 179 | 184 | 186 | 192 | 198 | |

WHEN DRAWING OFF.

| Time in minutes | — | — | — | 81 | — | — | — | 82 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 144 | 127 | 118 | 110 | 103 | 99 | 94 | 91 | 88 | 85 |
| ,, D | 213 | 213 | 212 | 200 | 174 | 156 | 144 | 136 | 132 | 125 |
| ,, H | 204 | 202 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 198 |
| ,, M | 204 | 204 | 204 | 204 | 204 | 203 | 203 | 203 | 203 | 203 |
| ,, O | 204 | 204 | 204 | 204 | 204 | 204 | 204 | 204 | 203 | 203 |
| ,, S | 212 | 212 | 212 | 196 | 174 | 160 | 148 | 138 | 132 | 126 |

| Time in minutes | — | 83 | — | — | — | 84 | — | — | — | 85 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 82 | 82 | 78 | 78 | 77 | 77 | 78 | 80 | 86 | 90 |
| ,, D | 121 | 116 | 111 | 111 | 110 | 108 | 104 | 98 | 96 | 95 |
| ,, H | 198 | 198 | 200 | 200 | 200 | 200 | 200 | 196 | 192 | 189 |
| ,, M | 203 | 203 | 203 | 203 | 203 | 201 | 196 | 196 | 178 | 176 |
| ,, O | 203 | 203 | 203 | 203 | 202 | 196 | 164 | 164 | 164 | 130 |
| ,, S | 120 | 118 | 150 | 150 | 145 | 118 | 106 | 100 | 98 | 96 |

## EXPERIMENT XVII.

Fig. 14 shows that the flow-pipe was connected in the same way as in the last experiment, *viz.*, to the top of the cylinder; but it will be observed that it was carried horizontal for some distance after leaving the cylinder, and that the branch was taken off this pipe on a level with the top of the cylinder. Thus, whilst the principle and the arrangement of the pipes was maintained, yet a very important change was introduced, which did away with the unequal head-pressure which had given the water travelling by way of the return-pipe an advantage of almost 1 lb. pressure over the water travelling by way of the flow-pipe during the draw-off, Experiment 15.

The effect this change (equalisation of pressure) had on the direction of the flow of water when the tap was open will be noticed on referring to Fig. 14 A. If the reader will compare the temperatures of the water at the points D, H, and S during the period of the draw-offs, he will see that when the branch was taken off the flow-pipe at the low-level the major portion of the water—in fact, practically all—was drawn through the boiler; whereas, in the present case, when the branch was taken off above the level of the cylinder the major portion was drawn from the top of the cylinder. The head-pressure being equal this route presented the least friction, the water having to flow through only four feet of pipe in order to reach the branch; whereas, by way of the return-pipe from the cylinder to the branch, it had to pass through 11 ft. 6 in. of pipe.

Possibly some readers may not at first sight be able to see how the direction of the flow of water may be determined from the readings of the thermometer. For the benefit of such the key to the solution may be given here.

If a gallon of water at 200 degs. be mixed with a gallon at 100 degs., the result will be two gallons at 150 degs. Now if, for example, we suppose that H registered 200 degs. and D 100 degs., and at the same instant S registered 150 degs., then it would follow that equal volumes of water were flowing in each direction to the branch.

But if H was at 200 degs. and D at 108 degs., and S at the same time registered 118 degs., then, since S is below the mean of 200 degs. and 108 degs., it is evident that more water was reaching S at the colder than the higher temperature; in other words, the greater portion of the water drawn off at S was flowing by way of the boiler.

On the other hand, if S was above the average temperature of H and D, it would show that more water was flowing from H than from D. In fact, the proportions from both directions can be estimated by this means if due allowance be made for the time

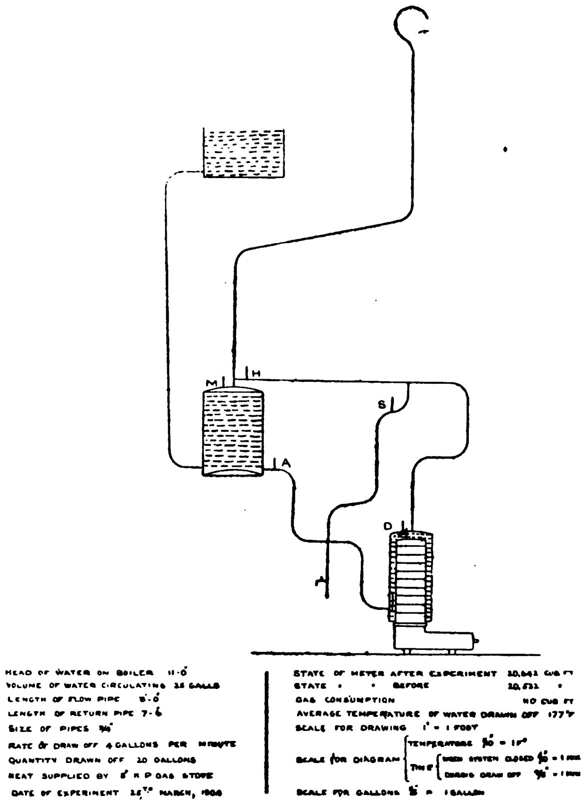

M
H
S
A
D
HEAD OF WATER ON BOILER 11-0"
VOLUME OF WATER CIRCULATING 25 GALLS
LENGTH OF FLOW PIPE 8'-0"
LENGTH OF RETURN PIPE 7-6
SIZE OF PIPES 3/4"
RATE OF DRAW OFF 4 GALLONS PER MINUTE
QUANTITY DRAWN OFF 20 GALLONS
HEAT SUPPLIED BY 8" R P GAS STOVE
DATE OF EXPERIMENT 26TH MARCH, 1906
STATE OF METER AFTER EXPERIMENT 20,642 CUB FT
STATE " " BEFORE 20,532 "
GAS CONSUMPTION 110 CUB FT
AVERAGE TEMPERATURE OF WATER DRAWN OFF 177°F
SCALE FOR DRAWING 1" = 1 FOOT
SCALE FOR DIAGRAM
TEMPERATURE 1/10" = 1°
TIME
WHEN SYSTEM CLOSED 1/10" = 1 MIN
DURING DRAW OFF 3/8" = 1 MIN
SCALE FOR GALLONS 1/8" = 1 GALLON

FIG. 14 (EXPERIMENT NO. 17).—SHOWING ARRANGEMENT OF APPARATUS.

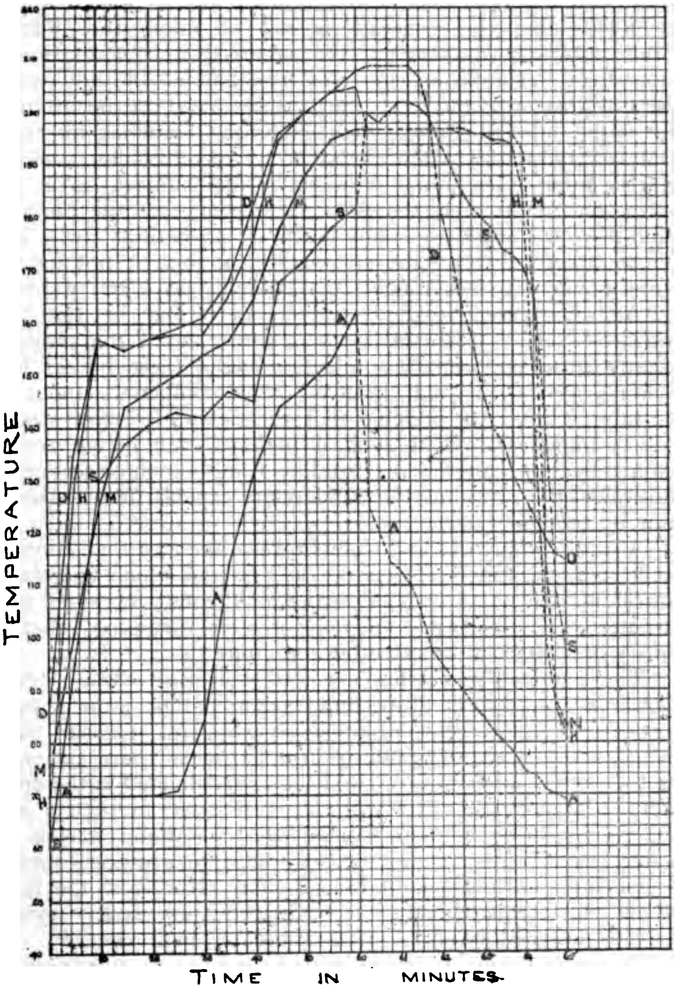


FIG. 14A (EXPERIMENT NO. 17).—DIAGRAM SHOWING RESULTS PLOTTED.

occupied by the water travelling from one thermometer to the other.

The results of these experiments demonstrate the scientific and intricate nature of the question of domestic hot water supply, and proves that the difficulty is not so much the heating of the water as drawing it off unmixed at its maximum temperature. In fitting up an installation of hot water apparatus great care and study must be bestowed on the arrangement of the different fittings, connections and branches, for there is only a very narrow margin between success and failure; and it is not so much in the broad principle of the subject, as in the working out of the minor details of the system, that the plumber is apt to find himself in conflict with some natural law. Too often we meet with hot water systems which, were it not for the "larger boiler and new range" trick, would be found wanting. No matter how defective a hot water apparatus may be, the "independent boiler" treatment is a sure cure; and if the plumber can only get an opportunity of injecting one of these boilers into the faulty system, he will hear no more complaints about no hot water. Yet it is possible that the same defective system could be remedied, and as good, or perhaps even better, results obtained by simply altering the position of the branch or secondary return-pipe, thus avoiding the unnecessary expense and trouble of fitting up the new boiler.

A careful study of these results reveals the fact that friction, specific gravity, and head-pressure are factors which exercise a controlling influence over the direction of the flow of water to a hot-water branch when it is taken off a circulating-pipe, whether primary or secondary, or any other loop pipe.

The plumber very often neglects to consult these factors when he is designing or fitting up a system of hot water supply, and does not sufficiently study how he may best marshal these forces, so that each may fulfil its own particular part, in order that the hottest water in the system may be delivered at the draw-off tap. Many systems met with are connected in such a way that, when a draw-off tap is opened, the cold water having the greater specific gravity and the advantage of position, outruns the hot water and reaches the branch first. Nor is it the rank-and-file of the trade who fall into such errors, for faulty systems are often designed and fitted up by those in "high places."

There are very many cylinder and secondary return systems connected so that, during the time the tap is shut, hot water is circulating past the branch; but immediately the tap is opened the direction of the flow is reversed and colder water drawn off. The same may also be said of many of the cylinder and tank systems which are adopted. To deal with these here would be out of place, as the results of experiments on the cylinder and tank system will be treated further on.

## TABULATED RESULT OF EXPERIMENT NO. 17.

WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|---|
| Thermometer A | 70 | 70 | 70 | 70 | 70 | 71 | 85 |
| ,, D | 86 | 135 | 157 | 155 | 157 | 159 | 161 |
| ,, H | 70 | 130 | 157 | 155 | 157 | 158 | 158 |
| ,, M | 75 | 100 | 125 | 144 | 147 | 150 | 154 |
| ,, S | 60 | 95 | 130 | 137 | 141 | 143 | 142 |

| Time in minutes | 35 | 40 | 45 | 50 | 55 | 60 | |
|---|---|---|---|---|---|---|---|
| Thermometer A | 114 | 132 | 144 | 148 | 153 | 162 | Draw-off. |
| ,, D | 168 | 182 | 196 | 200 | 204 | 208 | |
| ,, H | 165 | 176 | 195 | 200 | 204 | 205 | |
| ,, M | 157 | 165 | 178 | 188 | 195 | 197 | |
| ,, S | 147 | 145 | 167 | 172 | 178 | 182 | |

WHEN DRAWING OFF.

| Time in minutes | — | — | — | 61 | — | — | — | 62 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 125 | 120 | 115 | 113 | 110 | 105 | 98 | 95 | 92 | 90 |
| ,, D | 209 | 209 | 209 | 209 | 209 | 207 | 200 | 182 | 174 | 164 |
| ,, H | 197 | 197 | 197 | 197 | 197 | 197 | 197 | 197 | 197 | 196 |
| ,, M | 197 | 197 | 197 | 197 | 197 | 197 | 197 | 197 | 197 | 197 |
| ,, S | 200 | 198 | 200 | 202 | 202 | 201 | 199 | 194 | 190 | 185 |

| Time in minutes | — | 63 | — | — | — | 64 | — | — | — | 65 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 87 | 85 | 82 | 80 | 78 | 75 | 74 | 71 | 70 | 69 |
| ,, D | 157 | 147 | 140 | 137 | 131 | 127 | 123 | 119 | 116 | 115 |
| ,, H | 196 | 196 | 195 | 195 | 194 | 185 | 145 | 100 | 87 | 82 |
| ,, M | 196 | 196 | 196 | 196 | 196 | 193 | 165 | 115 | 88 | 83 |
| ,, S | 182 | 180 | 178 | 174 | 173 | 171 | 166 | 142 | 110 | 98 |

## EXPERIMENT XIX.

Having experimented with the different methods of connecting circulating pipes, attention was directed to the cold supply pipe, and the four following experiments deal with the methods adopted for connecting this pipe.

The best way to connect the cold supply to a hot-water system still remains an open question. Different authorities hold different views. One is of opinion that it should be connected to the side of the cylinder (near the bottom) at right angles; another that it should be connected to the bottom of the cylinder; while others think that this pipe should be taken direct to the boiler.

In all the previous experiments the cold supply was connected to the side of the cylinder at right angles, and the reader will be familiar with the behaviour of the water during a draw-off in the various systems when the cold supply was connected in this way.

It sometimes happens that the cold supply is trapped in order to prevent the water boiling back into the cold store cistern. When this questionable precaution is taken the pipe is in some

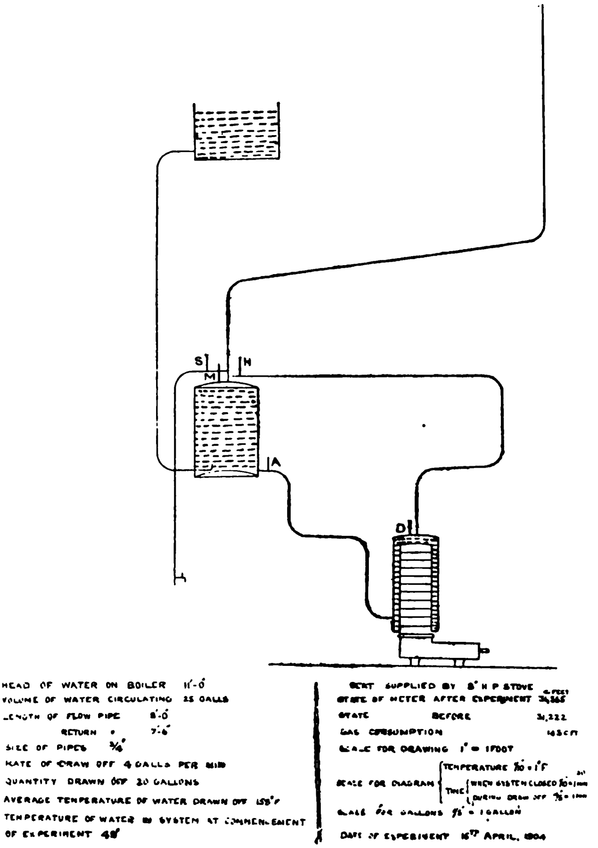

S
M
H
A
D
HEAD OF WATER ON BOILER 11'-0"
VOLUME OF WATER CIRCULATING 25 GALLS
LENGTH OF FLOW PIPE 8'-0"
RETURN " 7'-6"
SIZE OF PIPES ¾"
RATE OF DRAW OFF 4 GALLS PER MIN
QUANTITY DRAWN OFF 20 GALLONS
AVERAGE TEMPERATURE OF WATER DRAWN OFF 155°F
TEMPERATURE OF WATER IN SYSTEM AT COMMENCEMENT OF EXPERIMENT 48°
HEAT SUPPLIED BY 8" H P STOVE
STATE OF METER AFTER EXPERIMENT 34,365 C. FEET
STATE BEFORE 34,222
GAS CONSUMPTION 143 C.FT
SCALE FOR DRAWING 1" = 1 FOOT
SCALE FOR DIAGRAM
TEMPERATURE 1/10" = 1°F
TIME
WHEN SYSTEM CLOSED 1/50" = 1 MIN
DURING DRAW OFF 1/5" = 1 MIN
SCALE FOR GALLONS 1/8" = 1 GALLON
DATE OF EXPERIMENT 16TH APRIL, 1904

FIG. 15 (EXPERIMENT 19).—DRAWING SHOWING ARRANGEMENT OF PIPES.

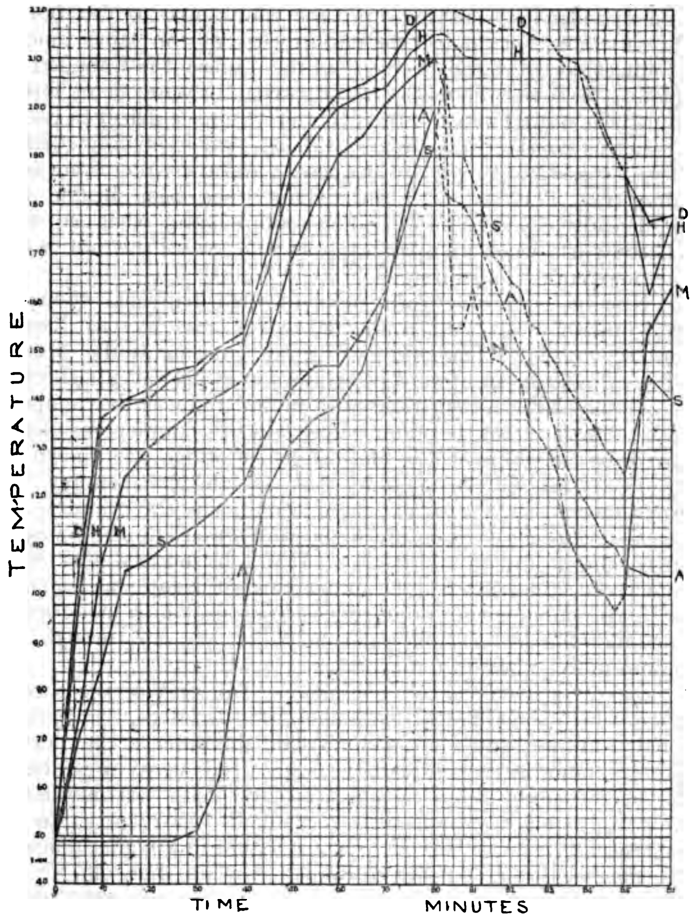


FIG. 15A (EXPERIMENT NO. 19).—DIAGRAM SHOWING RESULTS PLOTTED.

cases connected to the bottom of the cylinder or tank, and pointing in an upward direction. In fact, some members of the trade insist on turning this pipe upwards in all their systems, in order (as they say) to divert the cold water which enters at the bottom of the cylinder from rushing down the return-pipe to the boiler. While this may accomplish the end in view, at the same time it introduces complications worse than the disease it is intended to remedy; for is not the fact of a cold current of water being forced through the heated water in the cylinder or tank a defect in itself?

Let us consider the state of affairs that exists immediately before a hot water supply tap is opened, and the circumstances of a draw-off. The water in the cylinder has been heated and stored ready to yield a supply when required, and what we want to accomplish, when we open a tap, is to draw off the hot water at its maximum temperature.

Now let us consider for a moment what happens when the tap is opened in a system connected in the same way as Experiment 19, Fig. 15. The cold jet of water, entering at the bottom of the cylinder in an upward direction, forces its way up through the column of hot water, mixes with it, and reduces the temperature. The fact that the water behaves in this manner was clearly proved by Experiment 19, the results of which are shown by Fig. 15 A. As will be seen by Fig. 15, the cold supply was turned upwards by means of a short bend inside the cylinder, and the effect of thus directing the water in an upward direction is seen on referring to the plotted results. It will be noticed that thermometer M commenced to fall immediately the tap was opened, and S also commenced to fall soon afterwards, which fact goes to prove that the jet of cold water made its way up through the column of hot water in the cylinder.

Take, for instance, the readings at the end of the second gallon, which show that M had fallen from 210 degs. to 155 degs. in half a minute, and at the same instant the water at the bottom of the cylinder, at the point where A was fixed, stood at 181 degs., and at the point where O was fixed 198 degs. was registered, whilst the water drawn off was 190 degs. On referring to the diagram, Fig. 15 A, it will be seen that A was at a higher temperature than M throughout the entire period of the draw-off.

The principle of this method of connecting the cold supply has nothing to commend itself, and should be avoided; for as will be seen by the result of this experiment, the cold water travelled in a direct current to the top of the cylinder, as is evidenced by the readings of the thermometers M and O. It will be observed that the temperature at M was very much lower than at O, and instead of drawing off the hot water, it was mixed water that was delivered at the tap.

## Tabulated Result of Experiment No. 19.

### WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 49 | 49 | 49 | 49 | 49 | 49 | 51 | 62 | 97 | 121 | 131 |
| ,, D | 49 | 106 | 136 | 140 | 142 | 146 | 147 | 151 | 154 | 170 | 190 |
| ,, H | 49 | 100 | 133 | 139 | 140 | 144 | 145 | 150 | 152 | 166 | 186 |
| ,, M | 49 | 74 | 106 | 124 | 130 | 134 | 138 | 141 | 144 | 151 | 168 |
| ,, O | 49 | 49 | 68 | 116 | 127 | 133 | 137 | 140 | 143 | 147 | 162 |
| ,, S | 49 | 70 | 85 | 105 | 107 | 111 | 114 | 118 | 123 | 133 | 142 |

| Time in minutes | 55 | 60 | 65 | 70 | 75 | 80 | | 85 | 90 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 136 | 139 | 146 | 161 | 184 | 200 | Draw-off. | 106 | 104 | 104 |
| ,, D | 197 | 203 | 205 | 208 | 216 | 220 | | 186 | 177 | 178 |
| ,, H | 194 | 200 | 203 | 204 | 211 | 215 | | 186 | 162 | 177 |
| ,, M | 180 | 190 | 194 | 201 | 206 | 210 | | 110 | 154 | 163 |
| ,, O | 176 | 187 | 192 | 195 | 199 | 204 | | 105 | 145 | 159 |
| ,, S | 147 | 147 | 154 | 162 | 180 | 192 | | 125 | 145 | 140 |

### WHEN DRAWING OFF.

| Time in minutes | — | — | — | 81 | — | — | — | 82 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 183 | 181 | 180 | 177 | 171 | 166 | 161 | 155 | 151 | 147 |
| ,, D | 220 | 220 | 219 | 218 | 218 | 217 | 216 | 216 | 216 | 215 |
| ,, H | 215 | 213 | 211 | 210 | 210 | 210 | 210 | 210 | 210 | 210 |
| ,, M | 204 | 155 | 155 | 163 | 155 | 149 | 148 | 146 | 144 | 135 |
| ,, O | 203 | 198 | 195 | 187 | 181 | 171 | 170 | 164 | 157 | 150 |
| ,, S | 210 | 190 | 190 | 185 | 180 | 170 | 168 | 165 | 163 | 156 |
| Time in minutes | — | 83 | — | — | — | 84 | — | — | — | 85 |
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 145 | 139 | 132 | 127 | 122 | 119 | 115 | 111 | 110 | 106 |
| ,, D | 214 | 214 | 211 | 210 | 209 | 201 | 198 | 193 | 190 | 186 |
| ,, H | 210 | 210 | 210 | 208 | 208 | 206 | 200 | 195 | 190 | 186 |
| ,, M | 133 | 130 | 125 | 122 | 118 | 115 | 111 | 110 | 107 | 110 |
| ,, O | 141 | 138 | 132 | 127 | 122 | 118 | 116 | 112 | 108 | 105 |
| ,, S | 155 | 150 | 147 | 143 | 140 | 137 | 134 | 130 | 128 | 125 |

## EXPERIMENT XX.

On referring to the drawing, Fig. 16, it will be seen that the cold supply was turned downwards in the next experiment, in order to demonstrate the effect of breaking up the cold current, and causing the water to rise in a sheet instead of a current as in the last experiment. The writer has long been of the opinion that the cold supply should be treated in this way. The effect of diverting the cold water in this fashion will be seen by referring to the plotted diagram, Fig. 16 A.

Having proved what happens when a jet of water is turned in an upward direction, let us now consider it when it is diverted downwards (as in the case we are now dealing with). We know that when a jet of water strikes a flat surface it is broken up and spreads out in a sheet or plate, so that if the cold supply be made to strike the bottom of the cylinder or tank the current is broken up, and instead of the mixing which took place in Experiment 19,

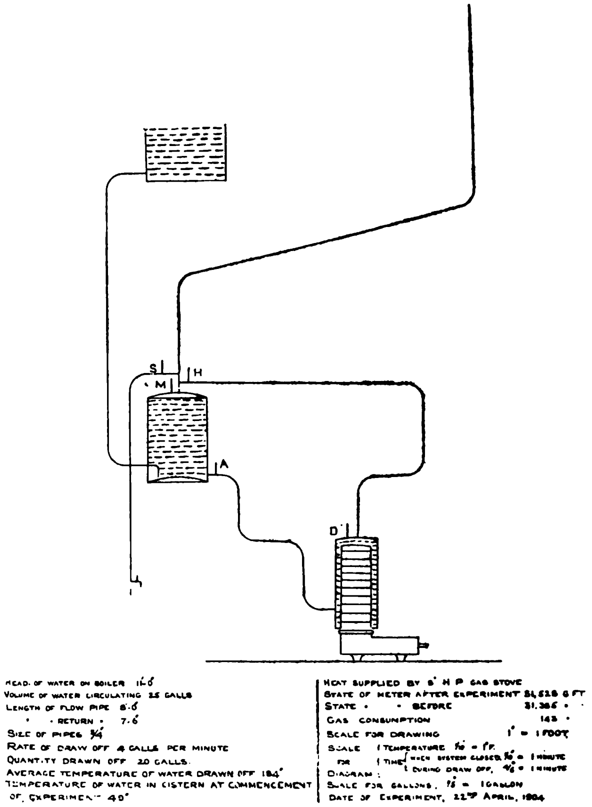

S
H
M
A
D
HEAD OF WATER ON BOILER 11-6
VOLUME OF WATER CIRCULATING 25 GALLS
LENGTH OF FLOW PIPE 8-6
" " RETURN " 7-6
SIZE OF PIPES 3/4"
RATE OF DRAW OFF 4 GALLS PER MINUTE
QUANTITY DRAWN OFF 20 GALLS.
AVERAGE TEMPERATURE OF WATER DRAWN OFF 184°
TEMPERATURE OF WATER IN CISTERN AT COMMENCEMENT OF EXPERIMENT 49°
HEAT SUPPLIED BY 8" H P GAS STOVE
STATE OF METER AFTER EXPERIMENT 31,528 C FT
STATE " " BEFORE 31,385 " "
GAS CONSUMPTION 143 "
SCALE FOR DRAWING 1" = 1 FOOT
SCALE FOR DIAGRAM: TEMPERATURE 1/10" = 1° F.
TIME WHEN SYSTEM CLOSED 1/10" = 1 MINUTE
DURING DRAW OFF 4/5" = 1 MINUTE
SCALE FOR GALLONS 1/8" = 1 GALLON
DATE OF EXPERIMENT, 22ND APRIL, 1904

FIG. 16 (EXPERIMENT NO. 22).—SHOWING ARRANGEMENT OF APPARATUS.

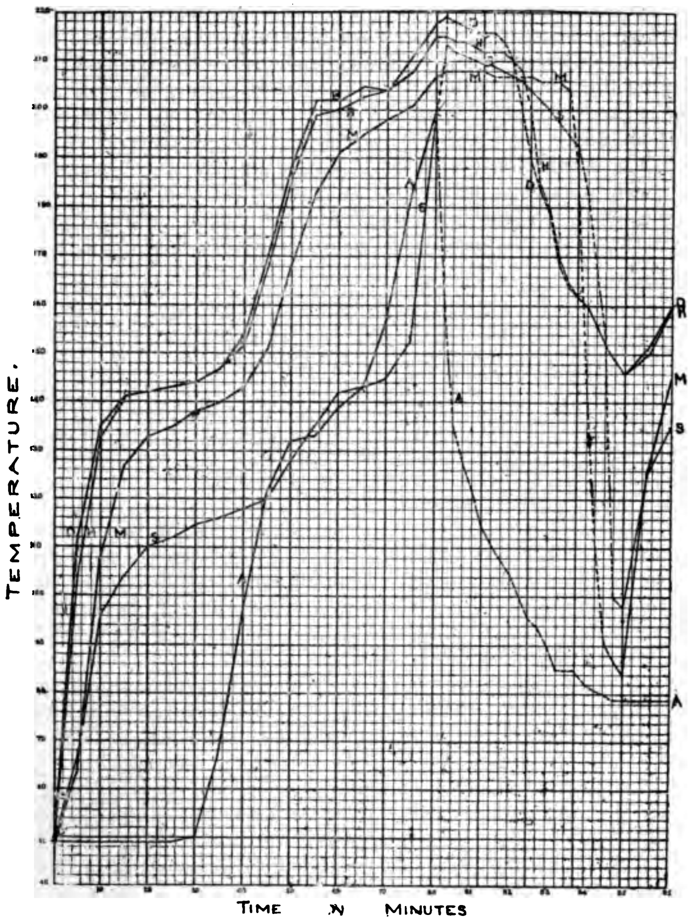


FIG. 16A (EXPERIMENT NO. 20).—DIAGRAM SHOWING RESULTS PLOTTED.

the water rises in the form of a sheet, or in layers, displacing the hot water in front of it, and mixing is reduced to a minimum, if not done away with altogether.

This fact is proved by the result of this experiment, and the reader will see by the plotted and tabulated results that the first fifteen gallons of water drawn off was at a very high temperature (an average of 202 degs.); and it will also be noticed that the heated particles of water which passed M and O in a downward direction during the period of heating, again passed these thermometers in the same order in an upward direction during the time the tap was opened.

On comparing the plotted results and also the temperature of the respective gallons of water drawn off in the case of Experiments Nos. 19 and 20, which are tabulated below, it will be seen that the difference in temperature is very noticeable:—

| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Experiment 19 Thermometer S | 210 | 190 | 190 | 185 | 180 | 170 | 168 | 165 | 163 | 156 |
| Experiment 20 Thermometer S | 213 | 212 | 211 | 210 | 209 | 209 | 208 | 207 | 206 | 204 |

| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Experiment 19 Thermometer S | 155 | 150 | 147 | 143 | 140 | 137 | 134 | 130 | 128 | 125 |
| Experiment 20 Thermometer S | 202 | 200 | 197 | 195 | 193 | 183 | 167 | 154 | 100 | 98 |

Take, for instance, the readings at the end of the fourteenth gallon:—Exp. 19, 143 degs.; Exp. 20, 195 degs.—a difference of 52 degs.; and if we compare the temperature of the water at the point M at the same instant, in each case the difference in temperature is still more striking:—Exp. 19, 122 degs.; Exp. 20, 204 degs.—a difference of 82 degs.

These facts convince one of the defect of connecting the cold supply to the bottom of the cylinder or tank and allowing the cold water to enter in an upward direction, yet we often see this method practised in so-called up-to-date systems.

In order to avoid confusion of lines, the curve O has not been plotted on diagrams Figs. 15 A and 16 A, but the reader would do well to study the readings given in the tabulated results of the two previous experiments, and plot the curves M and O in both cases, for comparison.

It will be noticed from the plotted results of Experiment 20 that during a certain period of the draw-off, colder water was delivered up the flow pipe than that at the top of the cylinder, but the difference in temperature at the points M and S was only a few degrees, S being at a higher temperature than M during the greater part of the time the tap was open, which fact was due to reasons already explained, and which need not be repeated here (See results of Experiments Nos. 6 and 6 A).

On comparing the average temperature of the water drawn off in the several experiments—particulars of which are given with the drawings of the various systems—it will be seen that the system we have just been dealing with yielded the highest average, and the writer has no doubt but that this method would give the best results in practice. Perhaps the greatest disadvantage would be the fact that it might yield excessively hot water. Even such would be a pardonable offence, especially in the morning when hot water is often at a premium.

### TABULATED RESULT OF EXPERIMENT NO. 20.

WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 49 | 49 | 49 | 49 | 49 | 49 | 50 | 67 | 98 | 121 | 132 |
| „ D | 49 | 112 | 135 | 141 | 142 | 143 | 144 | 147 | 154 | 170 | 189 |
| „ H | 49 | 105 | 133 | 141 | 142 | 143 | 144 | 147 | 152 | 168 | 186 |
| „ M | 49 | 63 | 108 | 127 | 133 | 135 | 138 | 140 | 143 | 151 | 168 |
| „ O | 49 | 49 | 78 | 121 | 132 | 135 | 138 | 140 | 143 | 149 | 164 |
| „ S | 49 | 67 | 96 | 104 | 110 | 112 | 115 | 116 | 118 | 120 | 128 |

| Time in minutes | 55 | 60 | 65 | 70 | 75 | 80 | | 85 | 90 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 133 | 139 | 143 | 157 | 183 | 200 | Draw-off. | 79 | 79 | 79 |
| „ D | 202 | 202 | 205 | 204 | 211 | 218 | | 146 | 151 | 160 |
| „ H | 199 | 200 | 203 | 204 | 208 | 215 | | 146 | 150 | 160 |
| „ M | 183 | 191 | 195 | 198 | 201 | 207 | | 84 | 126 | 145 |
| „ O | 180 | 191 | 195 | 198 | 200 | 206 | | 80 | 105 | 141 |
| „ S | 135 | 142 | 142 | 145 | 153 | 200 | | 98 | 125 | 135 |

WHEN DRAWING OFF.

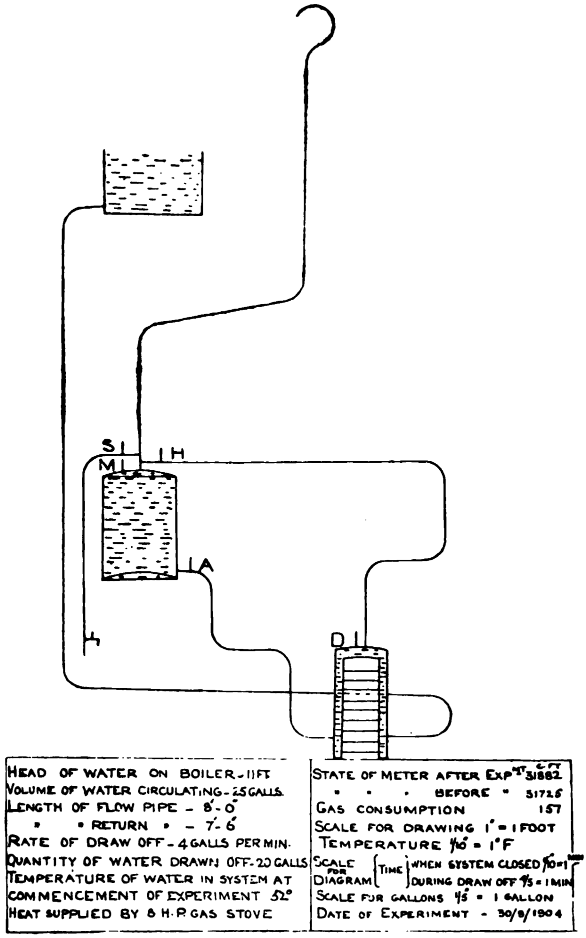
| Time in minutes | — | — | — | 81 | — | — | — | 82 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 160 | 135 | 128 | 122 | 115 | 111 | 108 | 105 | 100 | 96 |
| „ D | 219 | 218 | 217 | 216 | 216 | 216 | 214 | 210 | 200 | 190 |
| „ H | 215 | 214 | 214 | 213 | 212 | 212 | 212 | 210 | 208 | 200 |
| „ M | 208 | 208 | 208 | 208 | 208 | 207 | 207 | 207 | 207 | 207 |
| „ O | 207 | 207 | 207 | 207 | 207 | 207 | 207 | 207 | 206 | 206 |
| „ S | 213 | 212 | 211 | 210 | 209 | 209 | 208 | 207 | 206 | 204 |

| Time in minutes | — | 83 | — | — | — | 84 | — | — | — | 85 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 94 | 90 | 85 | 85 | 85 | 82 | 81 | 80 | 79 | 79 |
| „ D | 184 | 179 | 169 | 164 | 162 | 160 | 156 | 152 | 149 | 146 |
| „ H | 185 | 180 | 170 | 165 | 162 | 160 | 156 | 153 | 150 | 146 |
| „ M | 206 | 206 | 206 | 204 | 187 | 140 | 111 | 91 | 87 | 84 |
| „ O | 206 | 205 | 180 | 125 | 95 | 88 | 85 | 82 | 81 | 80 |
| „ S | 202 | 200 | 197 | 195 | 193 | 183 | 167 | 154 | 100 | 98 |

## EXPERIMENT XXII.

Fig. 17 shows that in Experiment No. 22 the cold supply was taken direct to the boiler, which method meets with considerable favour in some quarters.

The curves, Fig. 17a, representing the period of heating, are



HEAD OF WATER ON BOILER - 11 FT
VOLUME OF WATER CIRCULATING - 25 GALLS.
LENGTH OF FLOW PIPE - 8'-0"
" " RETURN " - 7'-6"
RATE OF DRAW OFF - 4 GALLS PER MIN.
QUANTITY OF WATER DRAWN OFF - 20 GALLS
TEMPERATURE OF WATER IN SYSTEM AT COMMENCEMENT OF EXPERIMENT 52°
HEAT SUPPLIED BY 8 H.P. GAS STOVE

STATE OF METER AFTER EXP^NT C FT 31882
" " " BEFORE " 31725
GAS CONSUMPTION 157
SCALE FOR DRAWING 1" = 1 FOOT
TEMPERATURE 1/10" = 1°F
SCALE FOR DIAGRAM { TIME { WHEN SYSTEM CLOSED 1/10" = 1 MIN
DURING DRAW OFF 1/5" = 1 MIN
SCALE FOR GALLONS 1/5" = 1 GALLON
DATE OF EXPERIMENT - 30/8/1904

FIG. 17 (EXPERIMENT 22).—DRAWING SHOWING ARRANGEMENT OF PIPES.

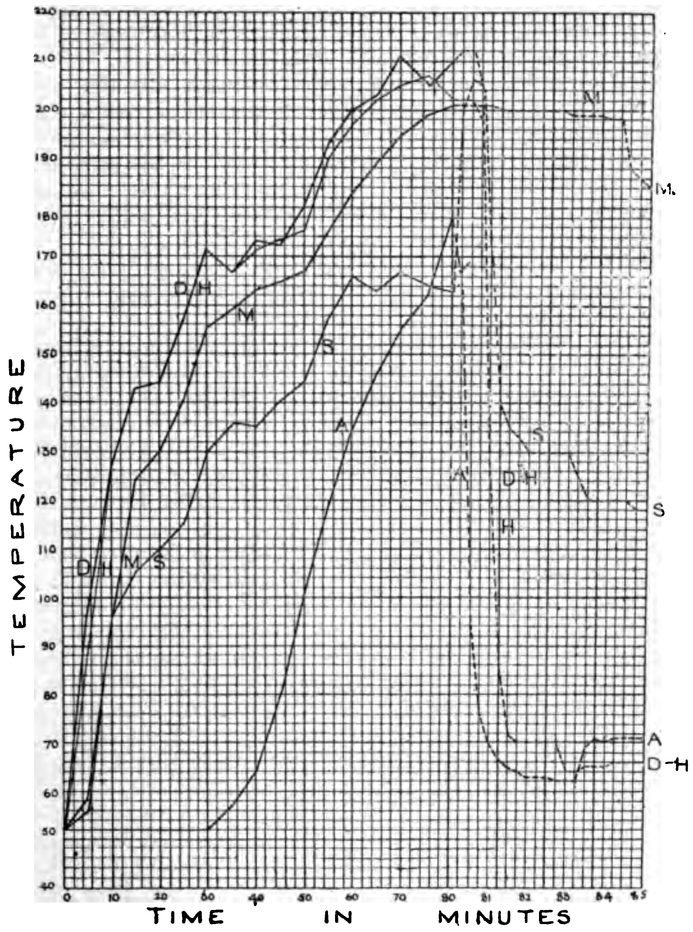


FIG 17A (EXPERIMENT No. 22).—DIAGRAM SHOWING RESULTS PLOTTED.

a little irregular when compared with those of other results. This was found to be due to a very slight dip in the flow pipe, which was not detected until after the experiment. It is from small details such as this that we may learn many useful lessons. The curves just mentioned should impress upon us the importance of fixing circulating pipes very carefully, either rising or falling, and avoiding dips—a fact which, by the way, we are all familiar with, but perhaps not so careful at all times to guard against.

The results obtained during the draw-off are just what would be expected. The cold water entering the boiler direct chilled it; the thermometer A commenced to fall almost immediately the tap was opened, and D commenced to fall at the end of the second gallon, and went down very rapidly during the next three gallons, the temperature of the water in the boiler being reduced 130 degs. in 45 seconds.

This is suggestive of unnecessary stress on the boiler, owing to the sudden contraction of the metal on being cooled by the cold water rushing in direct.

When the tap was opened the water travelled to the branch in two directions, through the flow pipe and also by the return pipe, equal volumes travelling in each direction, as will be seen by the dotted curves.

The flow pipe being connected to the extreme top of the cylinder, the cold water, travelling by way of the flow pipe, was delivered direct to the branch, and at a certain period of the draw-off water was issuing from the tap 70 degs. colder than the water at the top of the cylinder. Thus it will be seen that, by altering the position of a connection, entirely different results may be obtained; for we know that when the system was connected in the same way (*vide* last experiment) as the one we are now studying—except for the treatment of the cold supply—the best results of any were obtained; whereas, in the present case, we obtained one of the worst results.

### TABULATED RESULT OF EXPERIMENT NO. 22.

WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 57 | 64 |
| ,, D | 52 | 96 | 127 | 143 | 144 | 157 | 171 | 167 | 173 |
| ,, H | 52 | 90 | 127 | 143 | 144 | 157 | 171 | 167 | 171 |
| ,, M | 52 | 58 | 96 | 124 | 130 | 140 | 155 | 159 | 163 |
| ,, S | 52 | 56 | 96 | 105 | 110 | 115 | 130 | 135 | 135 |

| Time in minutes | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 80 | 101 | 119 | 134 | 146 | 155 | 162 | 178 | Draw-off. |
| ,, D | 172 | 180 | 193 | 200 | 203 | 211 | 205 | 210 | |
| ,, H | 173 | 175 | 190 | 197 | 202 | 205 | 207 | 202 | |
| ,, M | 165 | 167 | 175 | 183 | 189 | 195 | 199 | 201 | |
| ,, S | 140 | 144 | 157 | 166 | 163 | 167 | 164 | 163 | |

WHEN DRAWING OFF.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time in minutes | — | — | — | 81 | — | — | — | 82 | — | — |
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 164 | 95 | 77 | 70 | 67 | 65 | 64 | 63 | 63 | 63 |
| ,, D | 212 | 212 | 205 | 125 | 86 | 72 | 70 | 70 | 70 | 70 |
| ,, H | 202 | 202 | 198 | 140 | 90 | 75 | 72 | 69 | 69 | 69 |
| ,, M | 201 | 201 | 201 | 201 | 200 | 200 | 200 | 200 | 200 | 200 |
| ,, S | 200 | 206 | 205 | 170 | 140 | 135 | 133 | 130 | 130 | 130 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time in minutes | — | 83 | — | — | — | 84 | — | — | — | 85 |
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 62 | 62 | 62 | 69 | 71 | 70 | 71 | 71 | 71 | 71 |
| ,, D | 70 | 64 | 64 | 65 | 65 | 65 | 66 | 66 | 66 | 67 |
| ,, H | 69 | 67 | 65 | 65 | 65 | 65 | 67 | 67 | 67 | 66 |
| ,, M | 200 | 199 | 199 | 199 | 199 | 198 | 198 | 188 | 186 | 184 |
| ,, S | 130 | 130 | 125 | 120 | 120 | 120 | 120 | 120 | 118 | 118 |

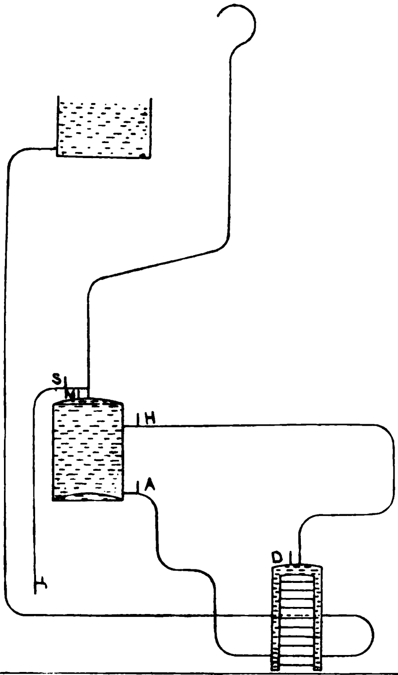
## EXPERIMENT XXIII.

In order to minimise the evil of delivering the cold water—which travelled through the flow pipe in the last experiment—direct to the branch, the flow pipe was connected to the side of the cylinder 8 in. from the top, as shown by Fig. 18.

The results obtained during the heating period present nothing new, but the curves representing the draw-off show that the changing of the position of the flow pipe had a very considerable influence for good on the temperature of the water drawn off.

It will be seen by the dotted curves, Fig. 18a, that the water travelled in two directions, by the flow and return pipes, and that the boiler was chilled to the same extent as in the previous case. The cold water entered the cylinder at the two points, A and H, mixed with the hot water in the cylinder, and during the early period of the draw-off a portion of the hot water at the top of the cylinder escaped through the branch past S ; but the mixed water had reached this point about the time the seventh gallon was being drawn off, and from this period on the thermometers M and S fell more or less rapidly during the time the next number of gallons were being drawn off.

As no doubt the reader is by this time acquainted with these diagrams, it is just possible that the curves explain the results of the experiments better than any language the writer can command. He will therefore not pursue the detailed explanation of the experiments on the cylinder system further, but will leave it to the reader to study the tabulated results and plotted curves, and compare the results obtained from the different systems experimented on.



| | |
|---|---|
| HEAD OF WATER IN BOILER - 11 FEET | HEAT SUPPLIED BY 8 H.P GAS STOVE |
| VOLUME OF WATER CIRCULATING - 25 GALLS | STATE OF METER AFTER EXP - 32,040 C. FEET |
| LENGTH OF FLOW PIPE - 8·6 | • • • BEFORE • - 31,882 |
| LENGTH OF RETURN • - 7·6 | GAS CONSUMPTION - 168 C FT |
| RATE OF DRAW OFF - 4 GALLS. PER MIN. | SCALE FOR DRAWING 1" = 1 FOOT |
| QUANTITY OF WATER DRAWN OFF - 20 GALLS | TEMPERATURE 1/10" = 1°F |
| TEMPERATURE OF WATER IN SYSTEM | SCALE FOR DIAGRAM {TIME} WHEN SYSTEM CLOSED 1/10" = 1 MIN. |
| AT COMMENCEMENT OF EXPERIMENT - 51° | DURING DRAW OFF 4/10" = 1 MIN |
| DATE OF EXPERIMENT 7/10/04 | SCALE FOR GALLONS 1/5" = 1 GALLON |

FIG. 18 (EXPERIMENT 23).—DRAWING SHOWING ARRANGEMENT OF PIPES.

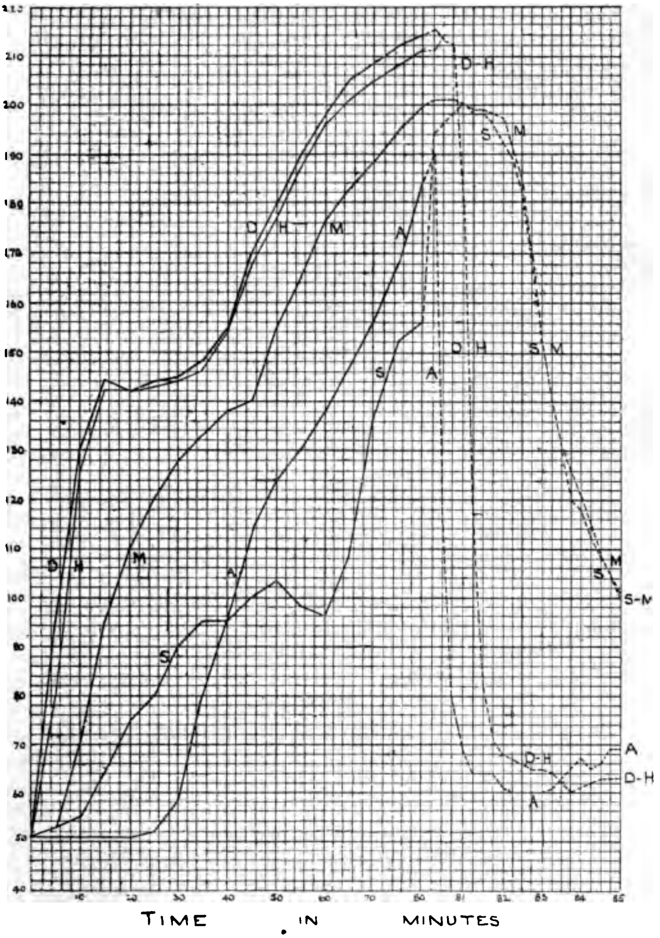


FIG. 18A (EXPERIMENT 23).—DIAGRAM SHOWING RESULTS PLOTTED.

## TABULATED RESULT OF EXPERIMENT NO. 23.

### WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 53 | 40 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 51 | 51 | 51 | 51 | 51 | 52 | 58 | 79 | 95 |
| ,, D | 51 | 95 | 130 | 144 | 142 | 144 | 145 | 148 | 155 |
| ,, H | 51 | 80 | 126 | 143 | 142 | 143 | 144 | 146 | 154 |
| ,, M | 51 | 53 | 70 | 95 | 110 | 120 | 128 | 133 | 138 |
| ,, S | 51 | 53 | 55 | 64 | 75 | 80 | 90 | 95 | 95 |

| Time in minutes | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 112 | 124 | 130 | 138 | 147 | 156 | 168 | 184 | Draw-off. |
| ,, D | 170 | 180 | 190 | 198 | 205 | 208 | 212 | 214 | |
| ,, H | 168 | 177 | 187 | 196 | 201 | 205 | 208 | 211 | |
| ,, M | 140 | 155 | 165 | 176 | 183 | 198 | 195 | 200 | |
| ,, S | 100 | 103 | 98 | 96 | 108 | 136 | 152 | 156 | |

### WHEN DRAWING OFF.

| Time in minutes | — | — | — | 81 | — | — | — | 82 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 190 | 115 | 80 | 69 | 64 | 64 | 64 | 61 | 60 | 60 |
| ,, D | 215 | 213 | 212 | 180 | 115 | 82 | 71 | 68 | 67 | 66 |
| ,, H | 211 | 214 | 214 | 150 | 120 | 80 | 75 | 65 | 65 | 65 |
| ,, M | 201 | 201 | 201 | 200 | 199 | 199 | 198 | 197 | 191 | 185 |
| ,, S | 194 | 196 | 198 | 200 | 198 | 198 | 196 | 192 | 189 | 182 |

| Time in minutes | — | 83 | — | — | — | 84 | — | — | — | 85 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 60 | 60 | 61 | 63 | 65 | 67 | 65 | 66 | 69 | 69 |
| ,, D | 65 | 65 | 64 | 62 | 60 | 61 | 62 | 63 | 63 | 63 |
| ,, H | 65 | 65 | 62 | 61 | 61 | 61 | 64 | 63 | 63 | 63 |
| ,, M | 170 | 152 | 140 | 131 | 126 | 121 | 115 | 109 | 105 | 101 |
| ,, S | 168 | 152 | 140 | 130 | 120 | 118 | 112 | 108 | 104 | 100 |

Whatever work we may be engaged in it is well at certain times to stop and review the past, correct or approve what has already been done, draw lessons from past experience and endeavour to map out a course for the future.

This habit the writer learned a good many years ago from an old plumber he was mate to. It was his custom when engaged in fitting up an arrangement of pipes, or carrying out other such work, to sit down on the side of the bath and take a long look at his work. To the casual observer he might have appeared to be acting the proverbial plumber—but no! for as he used to say to me:—"Lad, an hour spent each day in thinking about your work is never lost." I do not know how far this would meet with the approval of the present-day master, but be that as it may, the writer has often since proved the wisdom of the old journeyman's advice. Therefore if I linger a while to go over the ground already traversed, force of habit will, it is hoped, be ample apology.

Would that more of our fellow craftsmen practised the methods of my old mate, and when engaged on a job took a little more time to think out the "why and the wherefore" of the intricacies of the system they are engaged in producing, instead of throwing in the pipes and making connection in roughshod fashion, regardless of everything except trying to do two days' work in one, and only succeeding in making as many mistakes in one day as will occupy the next in setting right. Whereas if only a little time was spent in thought a lot of trouble and expense might be avoided.

It is not the object of these articles to lecture the unthinking members of the trade, nor yet to advocate preferential treatment for any particular method of fitting up water heating apparatus, but to establish principle based on experimental fact, which may be a guide to the members of the trade when designing or fitting up hot water systems.

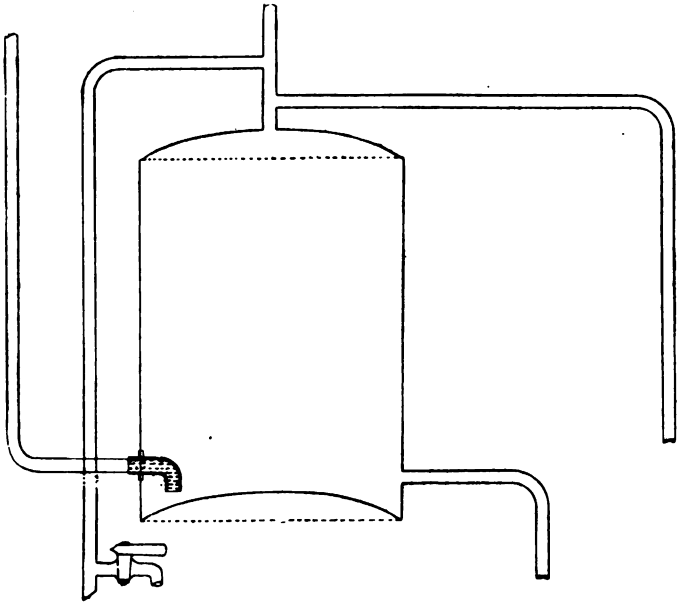


FIG. 19.—Showing the arrangements of the pipes which gave the best results in the foregoing experiments.

To lay down hard and fast lines would be beside the question, because an arrangement of pipes and fittings which may be suitable and can be fitted up in one house may be entirely unsuitable and impossible in another. Some local circumstance often presents itself, and the plumber is constantly called upon to bridge over the difficulty by arranging his fittings, runs, connections and branches to meet the requirements of each particular case.

A standard system being to a certain extent impracticable, it is therefore imperative that the plumber should be possessed of such knowledge as will enable him to successfully overcome each and every difficulty which from time to time crosses his path, and be capable of designing and fitting up a system suitable to the requirements and conditions as they present themselves.

If we glance rapidly over the diagrams already treated, perhaps the most striking feature will be the similarity between the various sets of curves, which represent the periods of heating; and if we study these curves in conjunction with the apparatus employed in producing them, we are met with the fact that the hot water was constantly being forced to the top, and that in its passage to the highest point it took the most direct route.

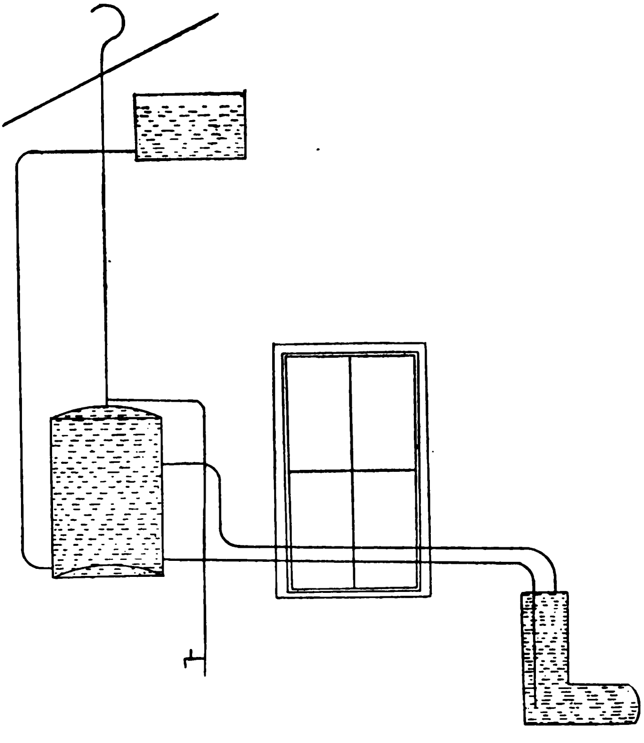


FIG. 20.—Showing a system fitted up with the circulating pipes crossing a window.

If owing to a natural law the water when heated is forced to the top, does it not follow that where practicable we plumbers should so arrange the pipes as to assist this law? If the hot water, when it enters the cylinder, rises to the top, it is only logical that in its passage thence it should not be compelled to pass through a colder region, as is the case when the flow pipe is connected to the side of the cylinder.

Thus, in theory the flow pipe should be connected to the top of the cylinder. But how will this work in practice? For the answer we have only to turn to the results of Experiments Nos. 7 and 20, and we find that the very best results were obtained when the flow pipe was connected in the manner stated. This method of connecting the flow pipe leaves nothing to be desired so far as the heating period is concerned, and when drawing off, this arrangement of pipes is capable of yielding the greatest supply and the hottest water. The risk of the cold water rushing down the return pipe through the boiler and up the flow pipe, and presenting itself at the branch before the supply of hot water in the cylinder is exhausted, is very remote, unless indeed the circulating pipes are very short and the branch very long. Under such circumstances there might be a rush of colder water coming up the flow pipe than that contained in the cylinder.

As water travels slowly through circulating pipes and very rapidly through branch pipes, it follows that with the arrangement of pipes shown in Figs. 10 and 16 more water will be drawn through the branch from the cylinder than the boiler is capable of ejecting up the flow pipe; hence the major supply will be drawn from the cylinder. The proportions from each source may be approximately estimated.

The velocity of flow through the circulating pipes being, practically speaking, constant in the case of each experiment, may be calculated as follows:—Take, for example, Experiment 15, Fig. 13A. On referring to the curves it will be seen that immediately heat was applied thermometer H commenced to rise, but the early heated water, which thus affected H, did not reach the thermometer A until the end of 30 minutes; that is to say, the water which left the boiler immediately heat was applied did not reach the point where A was fixed for the space of 30 minutes, but at the end of this period thermometer A commenced to rise. At this stage of the experiment all the water had been once round the system; in other words, it required a ¾ in. pipe 30 minutes to empty a 22-gallon cylinder, therefore the rate of circulation may be taken as 38 ft. per minute.

One foot of ¾ in. pipe contains ·0192 gal., or, roughly speaking, 52 feet of ¾ in. pipe contains 1 gallon, and 1,144 feet of ¾ inch pipe contains 22 gallons. Therefore, if 1,144 feet occupied 30 minutes in passing a given point, the velocity would be 38 feet per minute $\left(\frac{1144}{30}=38\right)$.

The velocity of flow through the branch when the tap was open may be taken as 208 feet per minute. The rate of draw-off being 4 gallons per minute, 208 feet of pipe contains this quantity of water $\left(\frac{4}{\cdot 0192} = 208\right)$.

If we apply these calculations to the draw-off in Experiments 7 and 20, we find that 208 feet of water was being drawn from the branch, 38 feet of which was drawn from the boiler; or, in other words, for every gallon drawn from the boiler $5\frac{1}{2}$ gallons were drawn from the cylinder. This is assuming that the rate of flow of water through the circulating pipes was not influenced by the draw-off.

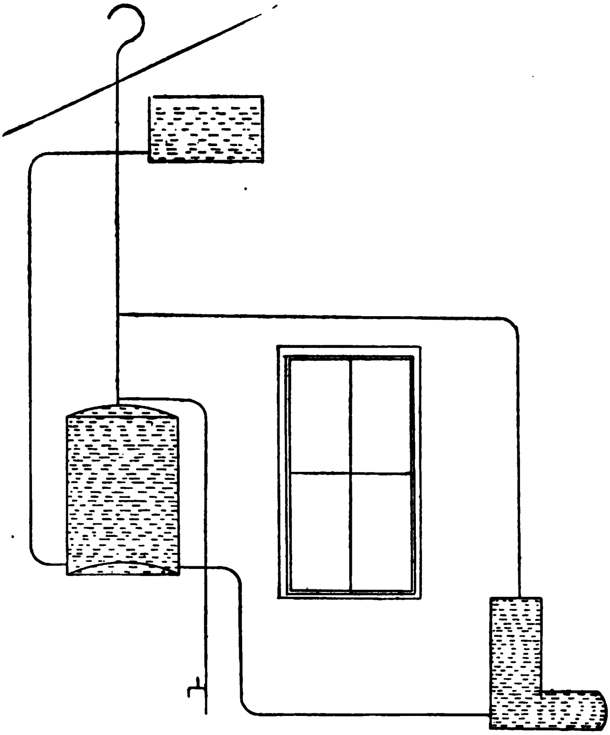


FIG. 21.—Showing how crossing windows, doors, &c., with circulating pipes may be avoided.

The boiler contained 3 gallons of water; therefore, before the 3 gallons had been ejected from the boiler, 16 gallons had been drawn from the cylinder, which accounts for the fact that cold water was not delivered up the flow pipe before the supply of hot water in the cylinder had been exhausted, in the case of Experiments 7 and 20.

These calculations are only approximate, but sufficiently correct for the present purpose of conveying to the practical man an idea of the rate of flow of water when circulating and also when drawing off. Of course the reader will be aware that a different boiler and different sizes of pipes, &c., would give different results as regards rate of flow.

On comparing the average temperature of the water drawn off, in the case of the several experiments which have already been dealt with, it will be found that the arrangement of pipes in Experiment 20 yielded the highest average, as well as the hottest water gallon for gallon. The arrangement in Experiment No. 7 comes next in order, and so on in the order tabulated below.

| No. of Experiment. | Time occupied in heating. | Average temperature of water drawn off. |
|---|---|---|
| 20 | 80 minutes. | 188 degrees. |
| *17 | 60 ,, | 177 ,, |
| 7 | 90 ,, | 176 ,, |
| 13 | 90 ,, | 168 ,, |
| 6 | 85 ,, | 166 ,, |
| 19 | 80 ,, | 158 ,, |
| 12 | 80 ,, | 157 ,, |
| [illegible]5 | 90 ,, | 152 ,, |
| 15 | 80 ,, | 145 ,, |

As an outcome of these experiments several hot water systems have been fitted up on the principle shown in Figs. 10 and 16. The writer has had an opportunity of subjecting some of these installations to the most severe test and has found them to give the greatest satisfaction, save that they yield excessively hot water.

Perhaps the most important feature of the principle thus established is the fact that it can be applied to overcome difficulties which often present themselves to the plumber when striking out the runs for circulating pipes. For instance, a door or window may come in the way; the top of the window may be above the top of the cylinder, as shown by Fig. 20, with the result that the circulating pipes are carried across the window, tending to mar the appearance of the room; whereas the return could be taken below the window or door, and the flow carried over the top and dropped into the top of the cylinder, as shown by Fig. 21, and the expansion taken off the higher point.

The practice of taking branches off the circulating pipes is one that should be avoided, first, because of the unnecessary strain on the pipes due to the sudden expansion and contraction of the pipes, especially if they are lead; second, if the branch be taken off the circulating pipe all the water in the cylinder may be drawn off (that is if the branch be taken off below the level of the cylinder), thereby increasing the risk of explosion; third,

---

* Note the temperature of water in the system at the commencement of Experiment (see Fig. 14a).

when branches are taken off the circulating pipes the hot water stored in the cylinder may not be drawn off, owing to reasons explained when treating results of Experiments 13, 15 and 17.

For these and other reasons, which need not be enumerated, branches for supplies off circulating pipes may introduce defects which it is well to avoid. The student of plumbing would do well to prove facts set forth in these articles for himself, and as Technical Schools for Plumbing have now been brought within reach of almost every tradesman who chooses to avail himself of the opportunities offered, there is no reason why every young plumber, before emerging from his apprenticeship, should not have been through a thorough course of research work in this, as well as in connection with other branches of the craft. By this means he may, when he goes forth to join the ranks of journeymen, be possessed of such practical experience and theoretical knowledge as will enable him to produce systems of water heating apparatus, which are not alone capable of heating water, but are also arranged in such a way that the passage of the water through the different arteries is so automatically regulated that the hottest water in the system may be delivered at the branch.

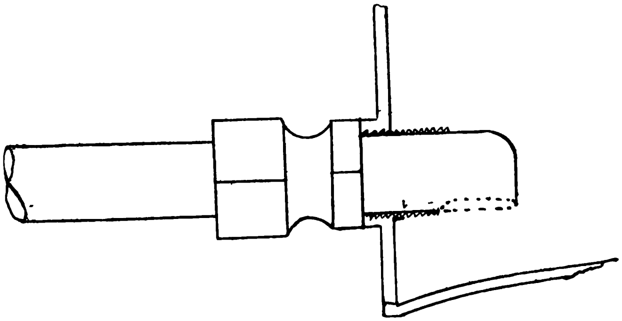


FIG. 22.—Coupling suitable for connecting the cold supply pipe to a cylinder, in which there is no hand-hole door.

The reader will no doubt be interested to know something of the quantity of gas used in each experiment. This will be found, amongst other particulars, given with each result. Take, for example, Experiment No. 20, Fig. 16:—

| | | |
|---|---|---|
| State of meter after experiment ... | 31,528 | c. ft. |
| do. before do. ... | 31,385 | „ |
| Gas consumption ... ... ... | 143 | „ |

The experiment lasted 95 minutes, so that the gas consumption (143 c. ft.) was at the rate of about 90·3 c. ft. per hour.

This, at the rate of 2s. 3d. per 1,000 cubic feet, represents an outlay of 3·8d., or, roughly speaking, 4d.

It cannot be hoped that gas will, to any extent, replace coal as a heating medium for hot water systems, yet the results of these experiments place hot water systems heated by gas within the sphere of practical possibilities. Take the case of Experiment No. 20. At the end of 80 minutes 20 gallons of water at the average temperature of 188 degrees were drawn off. If 20 gallons at 188 degrees be mixed with 40 gallons at 50 degrees, 60 gallons at 96 degrees will be the product.

Therefore sufficient hot water was heated in 80 minutes to give two warm baths of 30 gallons each at a cost of about 3d., being 1½d. per bath.

In many houses during the summer months the kitchen range is seldom used, and under such circumstances an installation of a gas-heating hot-water system would be a great boon. There is no reason why the system should not be so arranged that the water could be heated by the kitchen range boiler or by an independent gas boiler at will. Such an arrangement would, in many instances, be a great convenience, and would also tend to extend the trade's field of operations.

The boiler used in these experiments could be greatly improved upon, and thus even better results be obtained.

## EXPERIMENT VIII.

It is just possible that the first thing the vast majority of plumbers learn about hot water systems during the term of their apprenticeship is to avoid dipping the circulating pipes, the journeyman again and again cautioning the apprentice to guard against such a practice. But it too often occurs that the journeymen are either unable or unwilling to inform the apprentice why water will not circulate through pipes if they are dipped, either above or below the level of the boiler. Indeed, while all are agreed that circulating pipes should not be dipped, it is questionable if many trouble themselves to enquire the reason for this. The four following experiments deal with dips in the circulating pipes, and it is hoped that the results will explain why dips are defects, and at the same time show a remedy.

On referring to Fig. 23 it will be seen that the return pipe was dipped 12 inches, otherwise the connections were the same as Experiment 7, Fig. 10. The effect of thus dipping the return pipe will be seen from the curves Fig. 23A which represent the period of heating. It will be noticed (with surprise by some) that this dip had no evil effect on the circulation of water through the system, nor did it mar the heating of the water in the cylinder.

The writer must again rely on the curves to convey this fact,

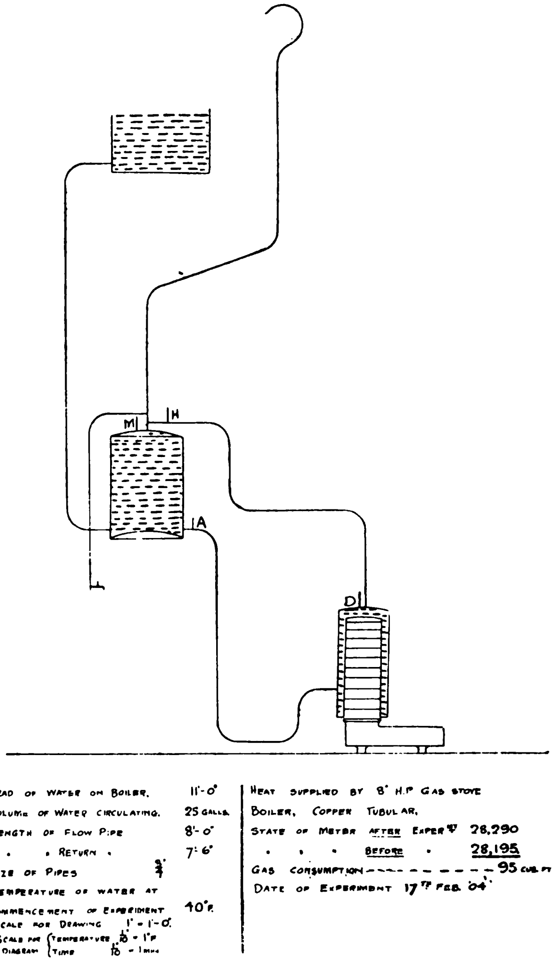

M
H
A
D
HEAD OF WATER ON BOILER. 11'-0"
VOLUME OF WATER CIRCULATING. 25 GALLS.
LENGTH OF FLOW PIPE 8'-0"
" " RETURN " 7'-6"
SIZE OF PIPES 3/4"
TEMPERATURE OF WATER AT COMMENCEMENT OF EXPERIMENT 40°F.
SCALE FOR DRAWING 1" = 1'-0"
SCALE FOR DIAGRAM TEMPERATURE 1/10" = 1°F
TIME 1/10" = 1 MIN
HEAT SUPPLIED BY 8" H.P GAS STOVE
BOILER, COPPER TUBULAR,
STATE OF METER AFTER EXPERT 28,290
" " " BEFORE " 28,195
GAS CONSUMPTION — 95 CUB. FT
DATE OF EXPERIMENT 17TH FEB. '04

FIG. 23 (EXPERIMENT NO. 8).—SHOWING ARRANGEMENT OF APPARATUS.

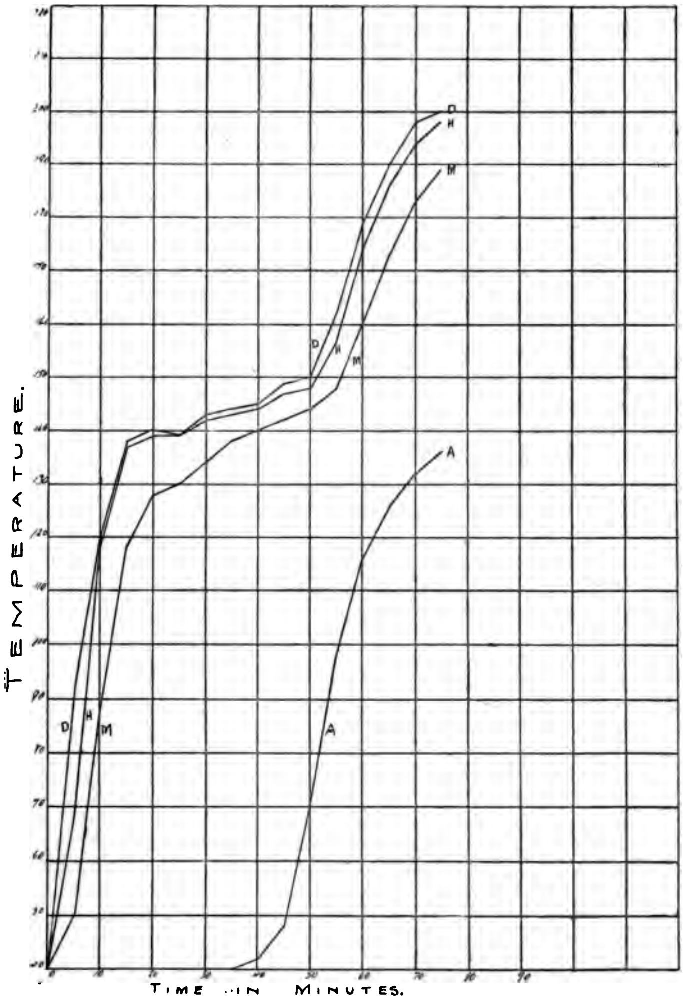


FIG. 23A (EXPERIMENT NO. 8).—DIAGRAM SHOWING RESULTS PLOTTED.

and if the reader will compare the curves produced by this experiment with those of Experiment No. 7, or, indeed, any of the previous experiments, he will see that the curves are exactly similar in the several cases.

Why should this not be so, considering the fact that the circulation of hot water through a system is due to the unequal specific gravity of water at different temperatures? So long as it is possible to establish unequal weights in the two columns of water, *i.e.* flow and return, circulation must and will take place.

Take, for example, a pipe bent a double U shape (as shown by Fig. 24) filled with water. The arrangement embodies the principle of a hot water system. If heat be applied at the point A, practically no movement in the water takes place; but if heat be applied to the bottom at B, circulation commences immediately; or if we apply heat a certain distance up one leg of the pipe at, say, C, circulation also takes place. It will be seen that the last instance presents an arrangement which embodies a dip in the return pipe.

The motive power which produces circulation is the difference in weight of the water in the return pipe and of that in the flow pipe. Hence if the column of water in the return pipe be heavier than that in the flow pipe, the water will circulate, a dip in the return pipe notwithstanding, as proved by the result of this experiment. The vertical distance that it is possible to successfully dip a return pipe is governed by the height and length of the flow pipe, and may be calculated by determining the difference in weight of the two columns of water, a fraction being allowed for loss of power by friction.

This point having been treated by Messrs. Box, Jones, and others in their works on heating, it need not here be gone into in detail.

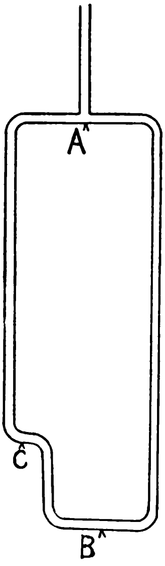


FIG. 24.

### Tabulated Result of Experiment No. 8.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 42 | 48 | 70 | 98 | 116 | 126 | 132 | 136 |
| ,, D | 40 | 92 | 120 | 138 | 140 | 139 | 143 | 144 | 145 | 149 | 150 | 162 | 179 | 190 | 198 | 200 |
| ,, H | 40 | 68 | 118 | 137 | 139 | 139 | 142 | 143 | 144 | 147 | 148 | 157 | 174 | 186 | 194 | 198 |
| ,, M | 40 | 50 | 88 | 118 | 128 | 130 | 134 | 138 | 140 | 142 | 144 | 148 | 160 | 173 | 183 | 189 |

## EXPERIMENT IX.

If a dip in the return pipe does not materially affect the circulation, why should a dip in the flow pipe not be allowable? This question will be best answered by the results of the following experiments.

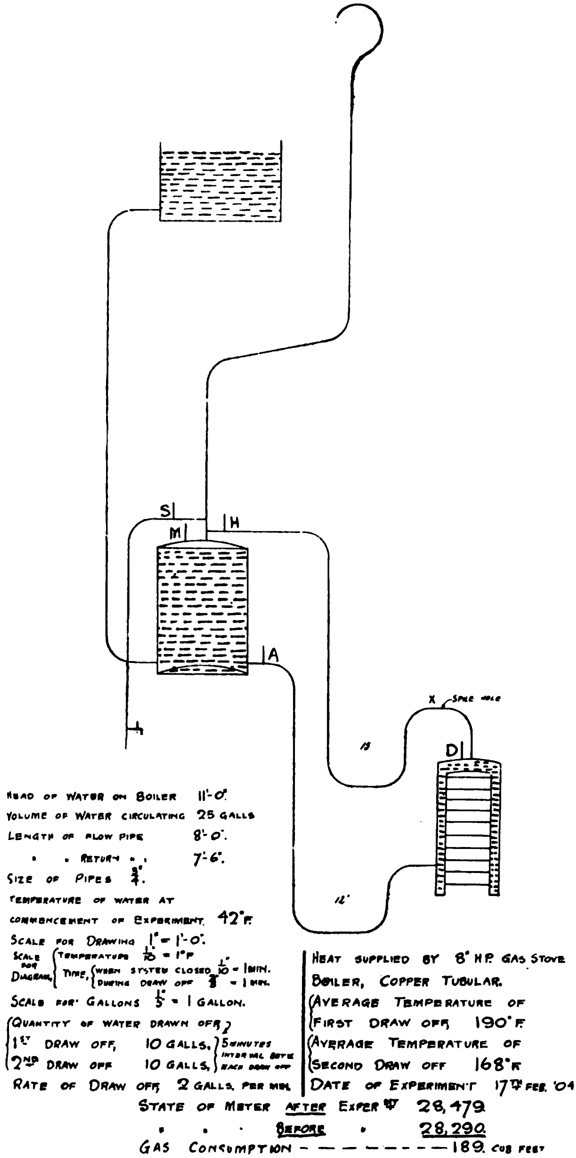
From Fig. 25 it will be seen that the return pipe was dipped the same as in the last experiment—12 inches; and the flow pipe was also dipped 15 inches. It should be noted that the dip in the return pipe was what might be termed a P-trap dip, whereas that in the flow pipe formed an S-trap.

When heat was applied the water commenced to circulate the same way as in any of the other experiments, as is evidenced by the fact that thermometer D (which registered 85 degrees at the commencement of the experiment) commenced to rise immediately heat was applied, being closely followed by H, and, as will be seen by the curves, Fig. 25A, this state of affairs continued for 10 minutes. At this period H was noticed to lag behind, which suggested a suspension of circulation. D continued to rise, and it will be observed that the travel of this thermometer is represented by a straight line for the first twenty minutes. On referring to curve A it will be noticed that between the 10 and 15 minutes this thermometer rose 4 degrees, and at the end of 20 minutes had reached 118 degrees; whilst during the same period H was falling (see curve). Thus it will be seen that the direction of the flow of water was reversed for the time being, and "confusion" is perhaps the term best calculated to describe what was happening inside the system, as indicated by the curves.

Between the 25 and 30 minutes a noise was heard as of steam rushing up the flow pipe. The experiment so far proved to the students that water will not circulate through an arrangement of pipes so dipped.

Not being satisfied alone with proving that such a system will not work, the experiment was continued with the object of showing why the dip in the flow pipe affected the circulation while the dip in the return pipe did not.

At twenty-five minutes a fine spile-hole was put in the crown of the dip at X, Fig. 25. When the needle was withdrawn it was found that what appeared to be steam had collected in the crown of the dip at X. When all the gas had escaped the spile-hole was closed, and it was observed that the water was circulating in the ordinary way, as will be seen by following the curves D and H. This continued for some time, till again the circulation was suspended. On opening the spile-hole air or steam, or more likely, a mixture of both, was blown off. This had the effect of allowing circulation to again take place. If the reader will study the curves and the printed particulars he will find that when the



Head of Water on Boiler 11'-0".
Volume of Water circulating 25 galls.
Length of flow pipe 8'-0".
" " Return " " 7'-6".
Size of Pipes ¾".
Temperature of water at commencement of Experiment 42°F.
Scale for Drawing 1" = 1'-0".
Scale for Diagram, Temperature 1/10" = 1°F; Time, when system closed 1/10" = 1 min., during draw off ⅜" = 1 min.
Scale for Gallons 1/5" = 1 Gallon.
Quantity of water drawn off, 1st draw off, 10 galls., 2nd draw off 10 galls., 5 minutes interval betw. each draw off
Rate of Draw off, 2 galls. per min.

Heat supplied by 8" H.P. Gas Stove Boiler, Copper Tubular.
Average Temperature of First Draw off, 190°F.
Average Temperature of Second Draw off 168°F.
Date of Experiment 17th Feb. '04

State of Meter after Exper^t 28,479.
" " " before " 28,290.
Gas Consumption — — — — — — — — 189. cub feet

Fig. 25 (Experiment 9).—Drawing Showing Arrangement of Pipes.

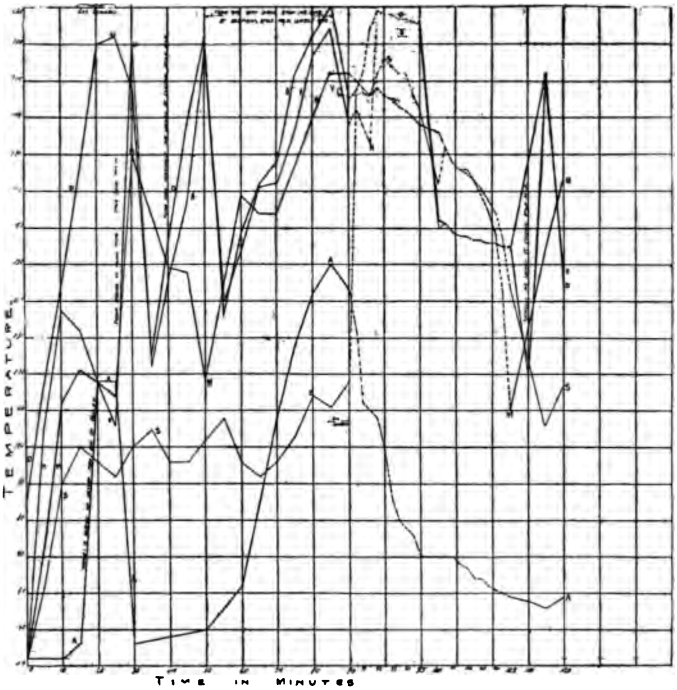


FIG. 25A (EXPERIMENT 9).—DIAGRAM SHOWING RESULTS PLOTTED.

spile-hole was open, and the air or steam which had collected in the crown of the dip was allowed to escape, the water circulated as if there were no dip in either flow or return pipe; but when the spile-hole was closed for about five minutes, circulation ceased.

During the experiment the students discovered that they could, by the manipulation of the spile-hole, stop and start the circulation at will; they also noticed that it required an expert hand to stop a spile-hole, especially when the water was issuing from it at almost boiling point.

From the plotted diagram it will be seen that for a period of 40 minutes (from 50 and 90 minutes) the spile-hole was kept slightly open, and that during this period the water in the system circulated in the ordinary way, as in any of the other experiments. The curves produced by the travel of the thermometer convey the fact better than a volume of words.

The fall in temperature between the 85 and 90 minutes was due to the gas being lowered to prevent the water in the boiler being raised to too high a temperature.

At the end of 90 minutes 10 gallons of water were drawn off at the rate of two gallons per minute. The result of the draw presented no particular feature of interest at present. When 10 gallons had been drawn off the tap was shut, and at the end of five minutes (represented by the ruled curves between the two sets of dotted curves) 10 gallons more were drawn off. The object of the draw-offs was to ascertain if drawing off water would affect the circulation, and it was found that the water commenced circulating after the draw-offs the same as in any of the other systems without dips. The experiment was continued 15 minutes after the second draw-off with the result indicated by the curves. The information gained by this experiment was that a gas collected in the crown or highest point of the dip in the flow pipe. When this gas was allowed to collect circulation ceased, but when the pipe was kept free from the gas, by allowing it to escape through an outlet at the highest point, the water circulated much the same as if no dips were in the pipes.

The question thus set to be solved was:—What was the nature of the gas which collected? Was it air or steam? If the former, where did it come from?

A member of the class, being of an inventive turn of mind, suggested that a condenser should be fixed on the top of the dip where the spile-hole had been.

One of the features of these experiments being that the students were allowed to put their ideas into practice, a piece of 1½ in. pipe was accordingly connected to the flow pipe by means of a piece of ¼ in. brass tube, the precaution being taken to carry from the top of the 1½ inch pipe a ¼ inch pipe to above the level of the water in the cold cistern, the small pipe being fitted with a stop-cock so that it could be used at will.

## TABULATED RESULT OF EXPERIMENT NO. 9.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 42 | 42 | 42 | 46 | 118 | 118 | 46 | 47 | 48 |
| ,, D | 85 | 117 | 143 | 175 | 210 | 212 | 198 | 125 | 157 |
| ,, H | 42 | 106 | 137 | 132 | 118 | 106 | 210 | 122 | 147 |
| ,, M | 42 | 72 | 112 | 121 | 118 | 114 | 180 | 164 | 149 |
| ,, S | 42 | 62 | 90 | 100 | 96 | 92 | 100 | 105 | 96 |

| Time in minutes | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 49 | 50 | 56 | 62 | 85 | 108 | 128 | 142 | 150 |
| ,, D | 188 | 212 | 136 | 159 | 172 | 178 | 202 | 212 | 220 |
| ,, H | 166 | 208 | 140 | 154 | 171 | 172 | 197 | 207 | 214 |
| ,, M | 148 | 118 | 145 | 169 | 164 | 164 | 177 | 190 | 202 |
| ,, S | 96 | 102 | 108 | 96 | 92 | 96 | 103 | 114 | 111 |

| Time in minutes | 90 | | 95 | 100 | | 105 | 110 | 115 | 120 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 143 | Draw-off | 70 | 70 | Draw-off | 59 | 58 | 56 | 59 |
| ,, D | 195 | | 216 | 162 | | 155 | 178 | 203 | 144 |
| ,, H | 189 | | 214 | 160 | | 155 | 120 | 200 | 148 |
| ,, M | 202 | | 188 | 186 | | 110 | 122 | 155 | 173 |
| ,, S | 118 | | 192 | 172 | | 144 | 123 | 106 | 117 |

WHEN DRAWING-OFF (FIRST).

| Time in minutes | — | 91 | — | 92 | — | 93 | — | 94 | — | 95 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 132 | 112 | 110 | 108 | 90 | 86 | 80 | 78 | 76 | 70 |
| ,, D | 197 | 202 | 214 | 219 | 218 | 218 | 217 | 217 | 216 | 216 |
| ,, H | 192 | 188 | 183 | 214 | 214 | 214 | 214 | 214 | 214 | 214 |
| ,, M | 200 | 198 | 196 | 198 | 196 | 195 | 193 | 192 | 190 | 188 |
| ,, S | 196 | 197 | 196 | 202 | 206 | 204 | 202 | 202 | 196 | 192 |

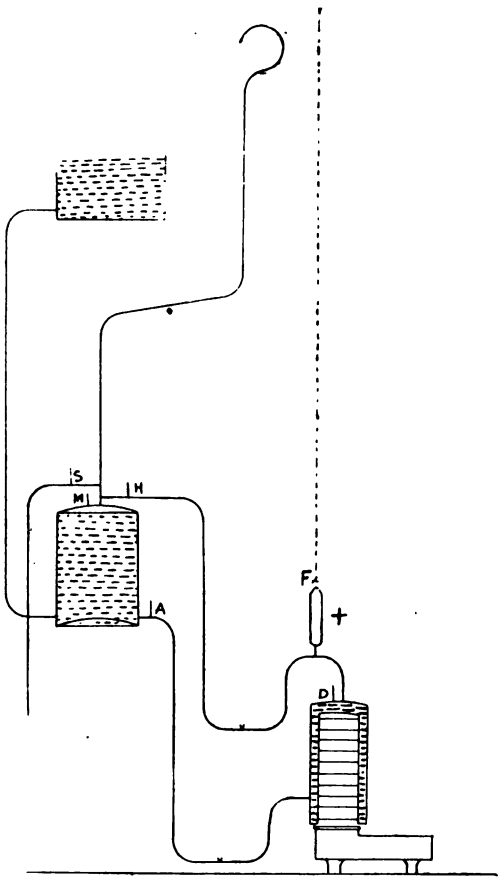
(SECOND).

| Time in minutes | — | 101 | — | 102 | — | 103 | — | 104 | — | 105 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 70 | 70 | 68 | 67 | 64 | 64 | 62 | 61 | 60 | 59 |
| ,, D | 161 | 159 | 158 | 158 | 157 | 157 | 156 | 155 | 155 | 155 |
| ,, H | 161 | 160 | 158 | 158 | 157 | 157 | 156 | 156 | 155 | 155 |
| ,, M | 182 | 178 | 176 | 176 | 173 | 169 | 165 | 158 | 142 | 110 |
| ,, S | 182 | 178 | 176 | 175 | 173 | 171 | 168 | 164 | 158 | 144 |

## EXPERIMENT X.

The arrangement of apparatus in Experiment No. 10 is shown by Fig. 26, and will be recognised as that of the previous experiment with the addition of the piece of 1½ in. pipe shown at X. The small ¼ in. pipe is shown by the dotted line. The stop-cock at F being shut, this ¼ in. pipe played no part in the early part of the experiment.

The effect of this container, as it may be called for want of a better name, will be seen by referring to the curves Fig. 26A, which explains the result at a glance. The reader will see by the curves that when heat was applied the water commenced to circulate as if the pipes had been fixed in the orthodox way, except that the rate of circulation was slightly slower than in some of the other experiments; otherwise the dips had no effect, at least for a considerable time.



Head of Water in Boiler, 11'-0"
Volume of Water Circulating 25 galls
Length of Flow Pipe 8'-0"
" " Return " 7'-6"
Size of Pipes ¾"
Temperature of Water at
commencement of Experᵗ 40°F
Scale for Drawing 1"=1'-0"

Scale for diagram { Temperature 1/16" = 1°F
Time 1/16" = 1 min
Heat supplied by 8" N.P. Gas Stove
Boiler, Copper Tubular.
State of Meter after Experᵗ 28,632
" " before " 28,478
Gas Consumption - - - - - - - - 154 cub. ft.
Date of Experiment 18th Feb '04

FIG. 26 (EXPERIMENT NO. 10).—SHOWING ARRANGEMENT OF APPARATUS.

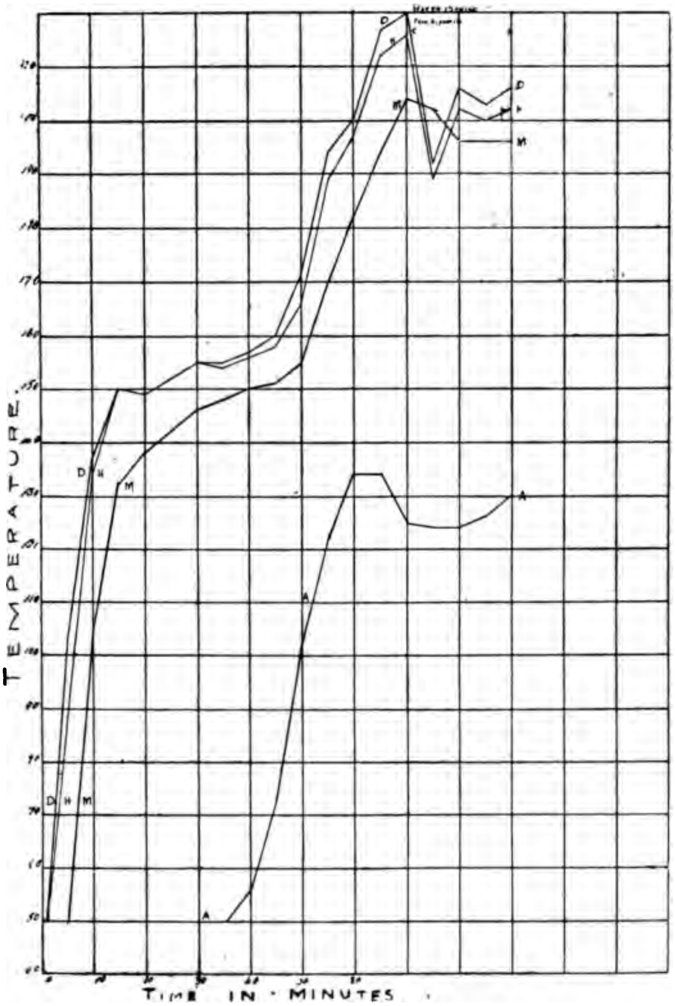


FIG. 26A (EXPERIMENT NO. 10).—DIAGRAM SHOWING RESULTS PLOTTED.

At the end of 70 minutes it was observed that the thermometer H ceased to rise and showed a tendency to fall, while D continued to rise, which tends to show that circulation was interrupted. The cock on the small vent-pipe at F was immediately opened, when it was observed that H again commenced to rise, indicating that circulation had been restored.

The container had the effect of preventing the gas collecting in the flow-pipe for a period of 70 minutes, but at this stage it was filled, and no longer capable of containing the gas that was being liberated from the water in the boiler; which fact suggests that the gas collected was not steam, otherwise it would have continued to condense. Therefore it was concluded that it was air. As there was no air in the system at the commencement of the experiment, where did the air which accumulated come from?

It is a well-known fact that water contains a certain amount of dissolved air, which is liberated when the water is heated. This air, on being liberated from the water in the boiler, being of less specific gravity than the water, rises to the top, and in the ordinary system escapes by way of the expansion pipe; but in the present case, when it reached the crown of the dip, having no means of ascent, it was imprisoned, and not being able to pass down through the water in the other side of the dip, collected at this point.

Circulation did not stop immediately the air commenced to collect, but when sufficient air had collected to fill the bore of the pipe and part the column of water, circulation was suspended until such times as the air was removed.

At first it may appear that the pressure of the water flowing from the boiler would displace the air, but it must be remembered that an equal pressure was also exerted in the opposite direction, so that the pressure on both sides of the air collected in the dip was equal. For this reason the air could not be displaced by the pressure, and it therefore became necessary to provide a means of escape.

### TABULATED RESULT OF EXPERIMENT NO. 10.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 56 | 73 |
| ,, D | 50 | 104 | 137 | 150 | 149 | 152 | 155 | 155 | 157 | 160 |
| ,, H | 50 | 90 | 134 | 150 | 149 | 152 | 155 | 154 | 156 | 158 |
| ,, M | 50 | 50 | 104 | 132 | 138 | 142 | 146 | 149 | 150 | 151 |

| Time in minutes | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 102 | 122 | 134 | 134 | 125 | 124 | 124 | 126 | 130 |
| ,, D | 171 | 194 | 200 | 217 | 220 | 192 | 206 | 203 | 206 |
| ,, H | 166 | 189 | 197 | 212 | 216 | 189 | 202 | 200 | 202 |
| ,, M | 155 | 176 | 182 | 194 | 204 | 202 | 196 | 196 | 196 |

## EXPERIMENT XI.

In order to fully demonstrate the effect produced by an air pipe taken from the crown of a dip, the container was removed, and a piece of ¼ in. pipe connected to the highest point of the flow pipe, aud carried up 3 ft. above the level of the water in the cold cistern, Fig. 27. Otherwise the apparatus was exactly the same as in Experiments 9 and 10.

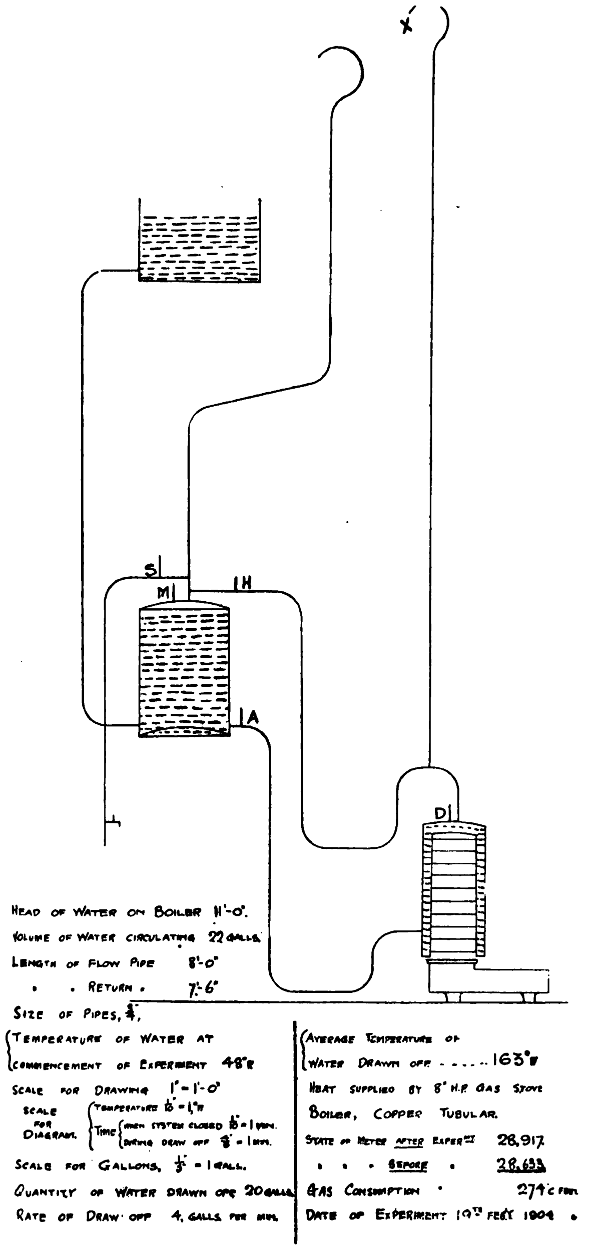
When heat was applied circulation commenced as usual, and it will be seen by the curves, Fig. 27A, that the water circulated quite smoothly, but slower than when there were no dips in the circulating pipes.

By the plotted results it will be seen that at the end of sixty minutes the water was leaving the boiler at 222 degrees—10 degrees above normal boiling point—while at the same time the water in the return pipe at A was only 130 degrees, and that 140 degrees was the highest temperature registered at the latter point. This was accounted for by the fact that, between the 55 and 80 minutes, water was flowing from the small exhaust pipe at X, Fig. 27, although this pipe was 3 ft. above the level of the water in the cold water cistern, and also higher than the expansion pipe. The cold water flowing into the cylinder to make good this loss had the effect of keeping this thermometer at the low temperature mentioned. This fact also accounts for the fall in temperature registered by D, H and M between the 65 and the 80 minutes (see Fig. 27A).

At the end of 80 minutes 20 gallons of water were drawn off It will be noticed that during the time the tap was open the temperature of the water at the points D and H was rising, and that during this period the circulation of the water through the flow-pipe was very slow, as is evidenced by the fact that the water which registered 204 degrees when passing D did not register its passage past H for a period of 2½ minutes. Thus, the water occupied 2½ minutes in travelling 8 ft., being at the rate of a little more than 3 ft. per minute.

The first fourteen gallons were drawn from the top of the cylinder (see curves S and M). It will be noticed that during the "draw-off" of the 15th, 16th, 17th and 18th gallons, S suddenly jumped up, and during this period was considerably higher than M; but during the 19th and 20th gallons the sudden rush of hot water up the flow-pipe had ceased, and at the end of the draw-off M recorded a temperature of 78 degrees and S 90 degrees, whilst at the same instant H and D stood at 214 degrees.

It will be interesting to a number of the trade to see the result of an experiment conducted on a system in which both circulating pipes were dipped; and while such an arrangement should be avoided, it is well to know that dipping both circulating



HEAD OF WATER ON BOILER 11'-0".

VOLUME OF WATER CIRCULATING 22 GALLS.

LENGTH OF FLOW PIPE 8'-0"

" " RETURN " 7'-6"

SIZE OF PIPES, ¾",

TEMPERATURE OF WATER AT COMMENCEMENT OF EXPERIMENT 48°F

SCALE FOR DRAWING 1" = 1'-0"

SCALE FOR DIAGRAM. TEMPERATURE 1/16" = 1°F

TIME WHEN SYSTEM CLOSED 1/16" = 1 MIN.

DURING DRAW OFF ⅛" = 1 MIN.

SCALE FOR GALLONS, ⅓" = 1 GALL.

QUANTITY OF WATER DRAWN OFF 20 GALLS.

RATE OF DRAW-OFF 4, GALLS. PER MIN.

AVERAGE TEMPERATURE OF WATER DRAWN OFF ...... 163°F

HEAT SUPPLIED BY 8" H.P. GAS STOVE BOILER, COPPER TUBULAR.

STATE OF METER AFTER EXPERMT 28,917

" " " BEFORE " 28,633

GAS CONSUMPTION " 274 C FEET

DATE OF EXPERIMENT 19TH FEBY 1904 "

FIG. 27 (EXPERIMENT 11).—DRAWING SHOWING ARRANGEMENT OF PIPES.

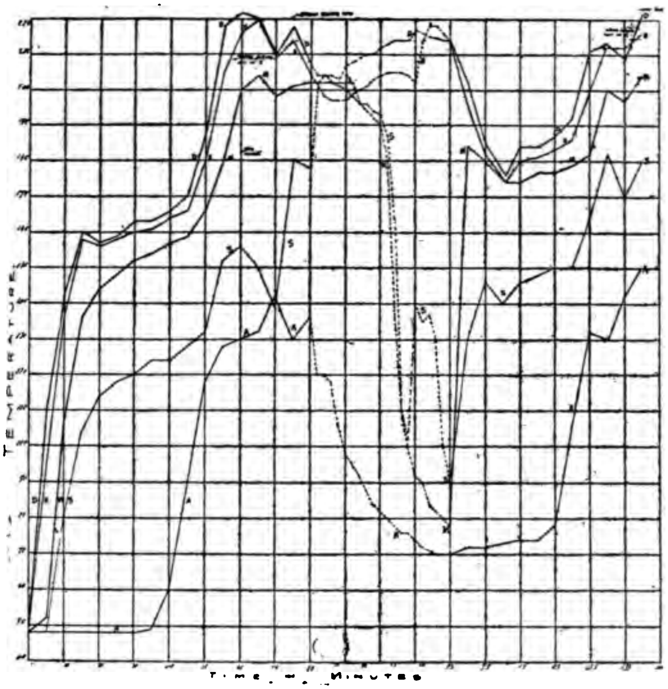


FIG. 27 A (EXPERIMENT 11).—DIAGRAM SHOWING RESULTS PLOTTED.

pipes is a practical possibility which may be attended with more or less success.

After twenty gallons had been drawn off the cock was shut and the experiment continued. It was found that the water circulated in the ordinary way and that nothing unusual took place until the water in the boiler had reached a high temperature, when water again commenced to flow from the small vent pipe. Otherwise there was no new development.

As already stated the writer in his youth received the usual caution against dips, and would to-day pass the word on to his mates, but while this is so, it does not follow that the members of the trade should not be well informed as to why dips are defects, and how and where it may be possible to employ them.

If you were to ask any of our leading surgeons regarding the amputation of a leg or arm he would inform you that amputation was a last resource, and should never be resorted to unless indeed there was no other remedy. Yet the surgeon has received special training in this particular branch of his profession, and so that he may be particularly expert, neither time, trouble nor expense have been spared on his training in order that when circumstances arise—as they do arise—he may be able to treat the case with skill.

So also should it be with the plumber. While taught to avoid dipping circulating pipes, he should also be informed why dips are defects; and how it is possible to overcome or minimise the defect by arranging the pipes in such a way that it may be impossible for air to collect in any part of the system. If this can be successfully accomplished water will circulate even when the pipes are dipped. But again let it be repeated, "Be careful."

In order to give the students a better assurance of the fact that when water is heated air is liberated and how this air collects in the crown of a dip, a hot water system in glass (Fig. 28) was fitted up by the members of the class.

A two-necked bottle was employed for a cold cistern, an ordinary lamp funnel for a cylinder, and a flask served the purpose of a boiler. Half-inch glass tubes were used for circulating and other pipes, these being connected to the fittings by devices of the students' own making. The flow-pipe was dipped as shown by the sketch. A few crystals of permanganate of potash were put into the flask in order to colour the water and so make the currents more distinct. Heat was supplied by an ordinary bunsen burner.

When heat was applied a movement in the water inside the flask was noticed, and soon afterwards a current of coloured water was seen passing up the flow-pipe, showing that circulation had commenced. When the coloured (heated) water entered the cylinder *it ascended to the top* in a direct current. The water

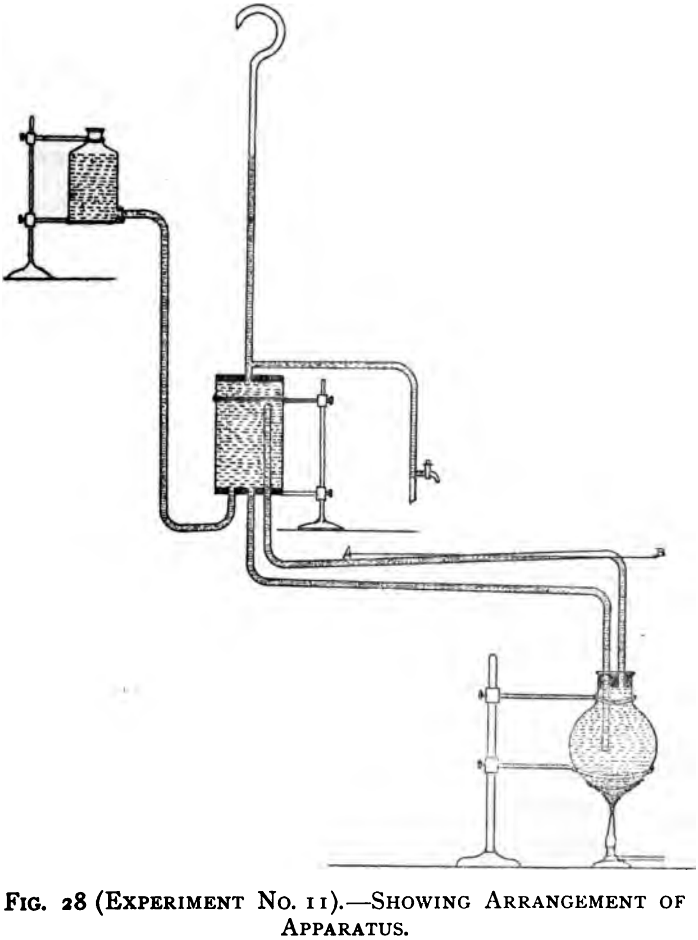


FIG. 28 (EXPERIMENT NO. 11).—SHOWING ARRANGEMENT OF APPARATUS.

continued to circulate for some time without anything unusual being observed, but at the end of about five minutes a few bubbles of air were seen to rise out of the boiler and collect in the flow-pipe, at first resembling the bubble in a spirit-level, which was continually being added to, until at last sufficient air had collected to fill the bore of the pipe.

The water continued to circulate until the air parted the column of water, when it was noticed that circulation was suspended. Heat was continued to be applied, and a little of the coloured water was forced up the return-pipe; but after a time, when the water in the flask had reached a high temperature, the air in the flow-pipe was displaced. Afterwards the water in the system again commenced to circulate as if no dip was in the pipe.

This piece of apparatus proved very useful for demonstrating to the students many other points in connection with hot water systems.

### TABULATED RESULT OF EXPERIMENT No. 11.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 49 | 60 | 88 |
| ,, D | 48 | 110 | 142 | 160 | 157 | 159 | 163 | 163 | 166 | 170 |
| ,, H | 48 | 94 | 136 | 158 | 156 | 158 | 160 | 161 | 164 | 166 |
| ,, M | 48 | 52 | 106 | 136 | 144 | 148 | 152 | 154 | 152 | 159 |
| ,, S | 48 | 48 | 80 | 104 | 114 | 118 | 120 | 124 | 124 | 128 |

| Time in minutes | 50 | 55 | 60 | 65 | 70 | 75 | 80 | | 85 | 90 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 118 | 128 | 130 | 132 | 142 | 130 | 136 | Draw-off | 70 | 72 |
| ,, D | 188 | 218 | 222 | 200 | 210 | 218 | 207 | | 214 | 202 |
| ,, H | 180 | 205 | 216 | 220 | 209 | 214 | 214 | | 214 | 195 |
| ,, M | 166 | 180 | 200 | 204 | 198 | 201 | 202 | | 78 | 184 |
| ,, S | 132 | 152 | 156 | 150 | 139 | 180 | 174 | | 90 | 130 |

| Time in minutes | 95 | 100 | 105 | 110 | 115 | 120 | 125 | 130 | 135 | 140 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 72 | 73 | 74 | 74 | 78 | 106 | 132 | 130 | 142 | 150 |
| ,, D | 185 | 176 | 184 | 184 | 187 | 192 | 211 | 213 | 209 | 222 |
| ,, H | 182 | 174 | 180 | 181 | 183 | 186 | 200 | 212 | 200 | 216 |
| ,, M | 180 | 174 | 174 | 174 | 177 | 179 | 182 | 200 | 197 | 204 |
| ,, S | 146 | 142 | 146 | 148 | 150 | 150 | 164 | 182 | 170 | 180 |

WHEN DRAWING OFF.

| Time in minutes | — | — | — | x1 | — | — | — | 82 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 136 | 120 | 120 | 118 | 106 | 95 | 92 | 88 | 84 | 82 |
| ,, D | 204 | 204 | 204 | 203 | 207 | 208 | 209 | 210 | 210 | 212 |
| ,, H | 201 | 198 | 197 | 197 | 197 | 199 | 200 | 201 | 203 | 204 |
| ,, M | 202 | 202 | 202 | 201 | 200 | 198 | 196 | 194 | 192 | 190 |
| ,, S | 202 | 200 | 202 | 202 | 202 | 200 | 196 | 196 | 194 | 193 |

| Time in minutes | — | 83 | — | — | — | 84 | — | — | — | 85 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 80 | 78 | 76 | 76 | 74 | 72 | 71 | 70 | 70 | 70 |
| ,, D | 213 | 214 | 214 | 214 | 217 | 216 | 215 | 215 | 214 | 214 |
| ,, H | 205 | 205 | 205 | 204 | 212 | 214 | 218 | 218 | 214 | 214 |
| ,, M | 180 | 140 | 110 | 100 | 92 | 90 | 84 | 82 | 80 | 78 |
| ,, S | 187 | 164 | 110 | 102 | 140 | 135 | 137 | 130 | 100 | 90 |

## EXPERIMENT XXI.

In order to demonstrate to the members of the class the part the pipe known as the expansion plays in a hot water system, the lead expansion pipe was replaced by a glass tube.

The water in this pipe was found to be on the same level as the water in the cold store cistern before heat was applied to the boiler. During the first period of the heating process there was no movement in the water in the expansion pipe, nor did the level of the surface of the water alter; but after a time the water in the expansion was noticed to rise, and a little later a bubble of air was seen to rush up this pipe followed by another and yet another, until at length there was an almost continuous stream of air bubbles passing up the expansion; the air bubbles sometimes carrying the water two feet above the level of the water in the cold cistern. It was found to be impossible at this stage to determine with any degree of accuracy the difference of level in the two columns of water, but roughly speaking the dead level of the water in the expansion was never more than two inches above the level of the water in the cold cistern.

The volume of the expansion of water on being heated in the system, as well as the volume of the air liberated, formed the subject of the next experiment.

The apparatus is shown by Fig. 29. It will be noticed that the cold supply pipe was disconnected from the cold store cistern (after the apparatus had been filled) and a small cock fitted on to the side of this pipe. A little more water was added until it commenced to run out at the cock, to which was attached a small piece of rubber tube carried down to a lower level.

A tube was also connected to the expansion pipe and carried down to a pneumatic trough in order to collect the air given off.

The pneumatic trough consisted of a lead dish that had been made by one of the juniors for a practice lesson in lead bossing; and for a graduated cylinder a large lozenge bottle, which had been carefully graduated, was pressed into service. In other respects the apparatus was similar to that employed in some of the previous experiments.

Almost immediately heat was applied water commenced to flow from the tap attached to the cold supply, which went to prove that the water commenced to expand early in the experiment; but there was no movement in the expansion pipe, except a slight rise in the level of water, nor was there any air given off for the space of one hour.

During the first hour the gas was kept burning low in order to discover what effect this would have on the circulation. It will be noticed from the curves, Fig. 29A, that this did not alter the

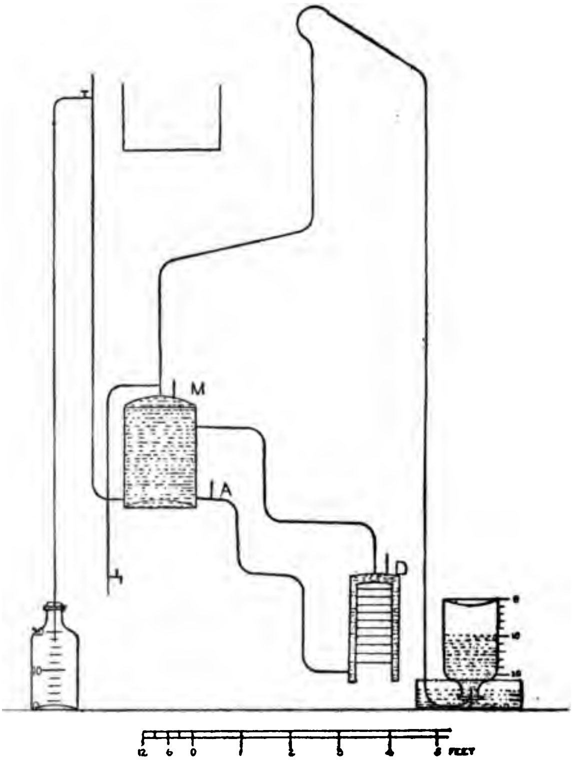


FIG. 29 (EXPERIMENT 21).—DRAWING SHOWING ARRANGEMENT OF PIPES.

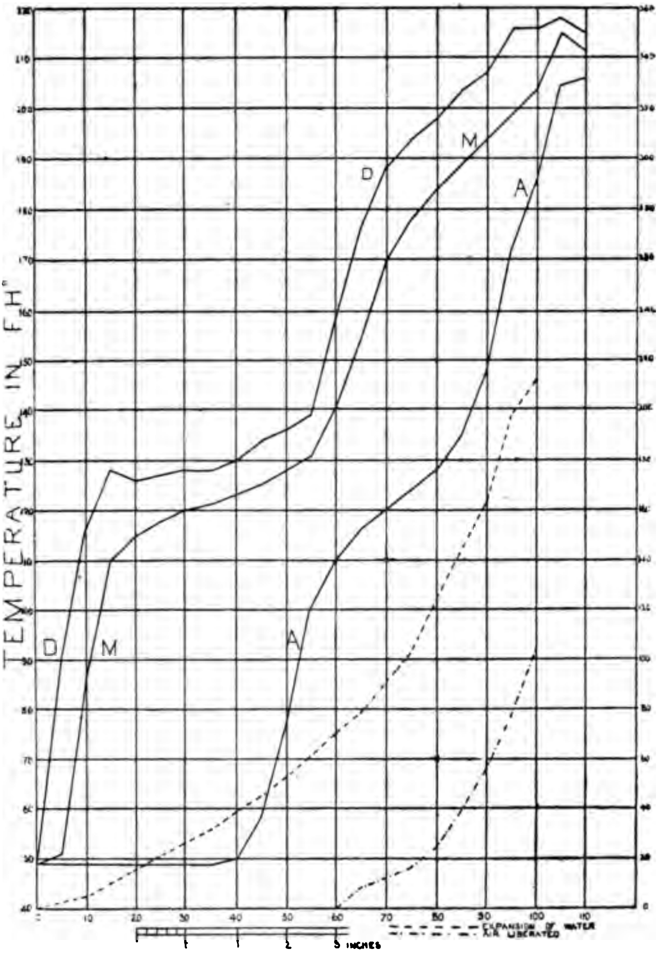


FIG. 29A (EXPERIMENT NO. 21).—DIAGRAM SHOWING RESULTS PLOTTED.

circulation, save in the rate of flow, and even in this respect the difference is scarcely perceptible.

The scale for time and temperature diagram is the same as all others already dealt with. The time scale for the expansion curve and the liberated air curve is also the same. For the expansion of water and the air displaced each vertical inch represents twenty cubic inches. This scale will be seen figured on the right hand side of the diagram. The expansion of the water is shown by the "dash" curve, and the volume of the liberated air is represented by the "dot and dash" curve.

At the end of sixty minutes a bubble of air was seen to pass up the expansion pipe and displace a corresponding volume of water in the graduated bottle, and from this period on, air was given off freely. (See plotted and tabulated results). At the end of 100 minutes the volume of the liberated air was found to be 105·25 cubic inches, and the volume of expansion of water was 212 cubic inches.

From this result it will be seen that in an ordinary hot water apparatus the expansion pipe is a means of escape for the air as it becomes liberated when the water is heated. The water as it expands is forced up the cold supply pipe into the cold store cistern. These are well-known facts, but will bear repeating.

For scientific purposes these results are of little or no value, as the apparatus was crude. The measuring vessels not being standard, it is possible that the results may be slightly inaccurate. At the same time the experiment was most interesting to the students, conveying the important facts that water expands on being heated, and also that at certain temperatures air is liberated; the results being sufficiently correct for the purpose of enabling the members of the class to form an idea of the volume of expansion and the amount of air given off.

## Tabulated Result of Experiment No. 21.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 50 |
| ,, D | 49 | 90 | 116 | 128 | 126 | 127 | 128 | 128 | 130 |
| ,, M | 49 | 51 | 86 | 110 | 115 | 118 | 120 | 121 | 123 |
| Vol. of Expansion .. ... | 0 | 2·12 | 4·25 | 11 | 16 | 21·75 | 27 | 32·50 | 39 |
| Vol. of Air Liberated ... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Time in minutes | 45 | 50 | 55 | 60 | 65 | 70 | 75 |
|---|---|---|---|---|---|---|---|
| Thermometer A | 58 | 78 | 100 | 110 | 116 | 120 | 124 |
| ,, D | 134 | 136 | 139 | 158 | 176 | 188 | 194 |
| ,, M | 125 | 128 | 131 | 140 | 154 | 170 | 178 |
| Vol. of Expansion ... ... | 45·50 | 53 | 60·50 | 71·50 | 78 | 92 | 102·50 |
| Vol. of Air Liberated ... | 0 | 0 | 0 | 0 | 8·5 | 12 | 17·25 |

| Time in minutes | 80 | 85 | 90 | 95 | 100 | 105 | 110 |
|---|---|---|---|---|---|---|---|
| Thermometer A | 128 | 135 | 148 | 172 | 186 | 205 | 206 |
| ,, D | 198 | 204 | 207 | 216 | 216 | 218 | 215 |
| ,, M | 184 | 189 | 194 | 199 | 204 | 215 | 211 |
| Vol. of Expansion ... ... | 122·25 | 143 | 163·25 | 197 | 212 | — | — |
| Vol. of Air Liberated ... | 26 | 39 | 56·25 | 78 | 105·25 | steam | |

## EXPERIMENTS II & III.

In order to subject the method of heating at or below the level of the boiler to an experimental test, a small eight-loop radiator, situated in an adjoining class-room, was connected to the boiler. This apparatus is shown by Fig. 30.

For convenience the flow-pipe was connected as shown by the drawing. This in practice might be objectionable, but in the present case it answered the purpose. The return-pipe had to pass below a door, and was dipped as shown. The length of the flow-pipe was 40 feet and the length of the return-pipe was 35 ft. The flow was carried up 5 ft. above the boiler; the pipes were ¾ in. lead; and the same boiler and stove were employed.

The first experiment had to be abandoned owing to an accident to one of the thermometers, nor was this the only occasion on which a thermometer came to grief. They who play at bowls must expect rubbers, and they who work with glass apparatus fitted to pipes under pressure may expect breakages.

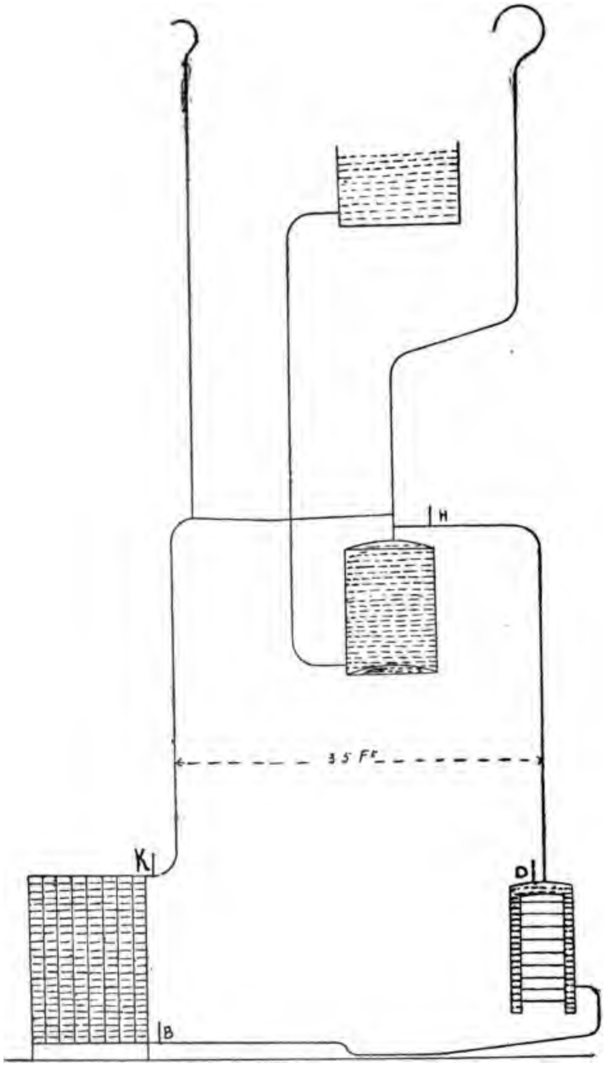
One of the results of the experiment was to discover that the flow-pipe was dipped. This pipe had been laid on top of a wallplate which was off the level, owing to a sinkage in the building. Although the flow-pipe was dipped, the radiator heated, and to all outward appearance the system was working perfectly (the dip in the flow-pipe was only about equal to the bore of the pipe), yet the tell-tale thermometers showed that the circulation was not regular, the flow of water being affected by the air, somewhat in the same way as water in a gas pipe affects the passage of gas.

Before the second experiment was commenced a small pipe with cock attached was fitted on the highest point of the flow. The cock being kept shut, this pipe did not act save when the cock was opened.

The result of this experiment is shown by Fig. 30A, and it will be seen at a glance that the system was not working satisfactorily; yet had it not been for the thermometer, it might have been pronounced a success, for the radiator heated well.

The question which presented itself was, What caused the ebb and flow circulation? Was it due to the dip in the return-pipe, or to the radiator being below the level of the boiler? or was the dip in the flow-pipe wholly responsible?

During the next experiment the cock on the small air-pipe



HEAD OF WATER ON BOILER, 13′-0″
LENGTH OF FLOW PIPE 40′-0″
" " RETURN " 35-0″
{TEMPERATURE OF WATER AT COMMENCE-
{MENT OF EXPERIMENT 40°F.
SCALE FOR DRAWING 1″ = 1′-0″.
SCALE OF {TEMPERATURE 1/16″ = 1°F.
DIAGRAM {TIME 1/16″ = 1 MIN

DATE OF EXPERIMENT 10TH FEB. '04
{BOTTOM OF RADIATOR BELOW
{BOTTOM OF BOILER, 9″
HEIGHT OF FLOW ABOVE BOILER, 5′-0″
" " " RETURN 8′-0″
STATE OF METER AFTER EX 27,986.
" " " BEFORE " 27,815.
GAS CONSUMPTION. - - - - - 171, C. FEET

FIG. 30 (EXPERIMENTS NOS. 2 & 3).—SHOWING ARRANGEMENT OF APPARATUS.

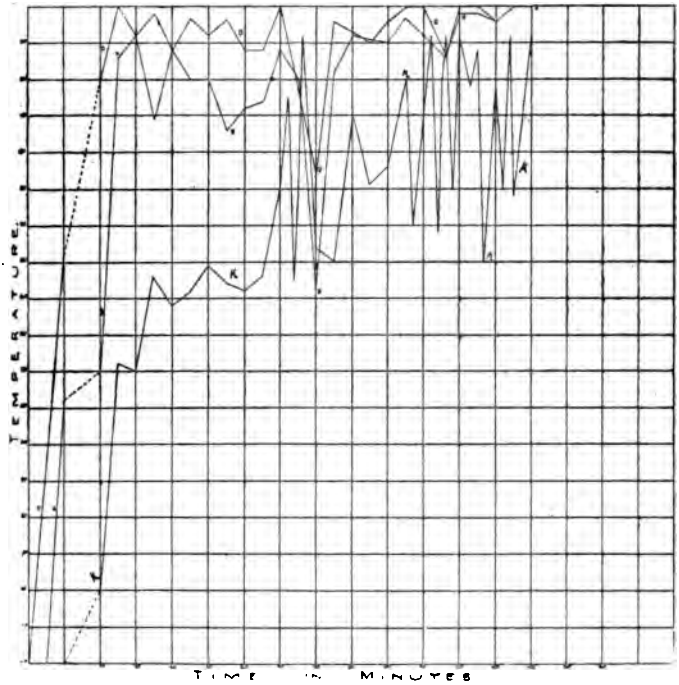


FIG. 30A (EXPERIMENTS NOS. 2 & 3).—DIAGRAM SHOWING RESULTS PLOTTED.

was kept open, and this had the effect of doing away with the ebb and flow circulation, as will be seen by the curves Fig. 31A. The apparatus, as will be seen by Fig. 31, was exactly similar to Fig. 30, except that in the latter the cock on the air vent was kept shut, whereas in the former it was kept open.

The curves representing these two experiments explain themselves, and shewed that when the air was allowed to collect in the flow-pipe the circulation was irregular, but when it was allowed to escape the water circulated smoothly, and that the radiator did heat although it was 35 ft. away from the boiler and on a lower level.

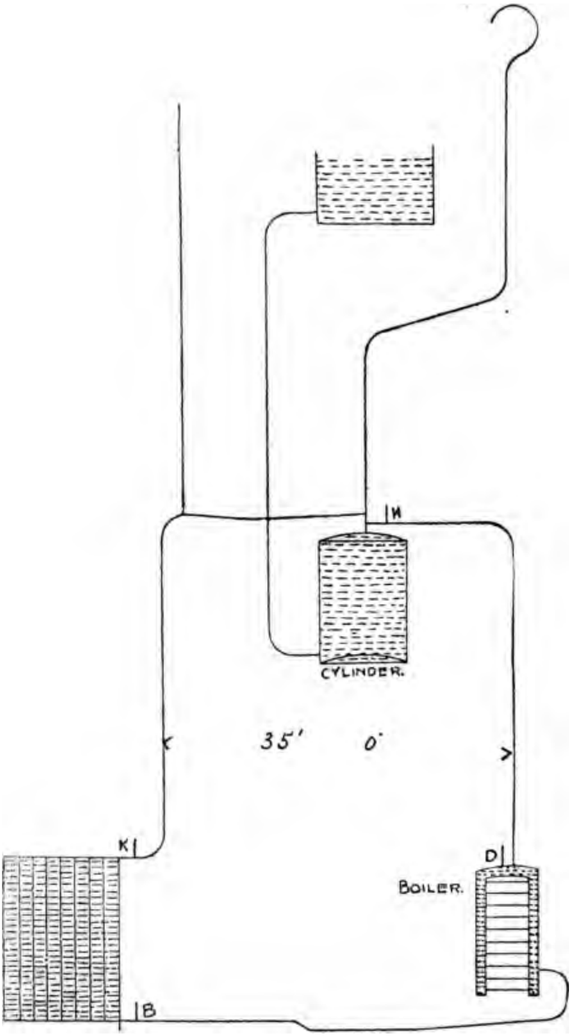
During the first 30 minutes of the experiment the gas was burning full but was afterwards lowered, and kept burning very low during the remainder of the experiment. It will be seen that the water in the boiler was at a very high temperature. The pipes being only ¾ in. had the effect of making the circulation sluggish. It may be added that the pipes were exposed and had to pass through a cold, draughty corridor, which accounts for the great loss of heat between the boiler and the radiator.

Although the radiator in the present case heated perfectly, it would not be safe to place too much reliance on this result, seeing there was only one radiator on the system, which considerably simplified the heating. The writer hopes later to give the results of further experiments conducted on a heating system fitted up in a small villa, which will no doubt prove of a more practical nature.

There is perhaps no more perplexing question in connection with heating presented to the plumber than the one involving the dipping of pipes and heating below or on the level of the boiler. On no account should the plumber attempt to carry out such work unless he has made a thorough scientific study of the principles of hot-water circulation, for if he relies on rule-of-thumb methods he may probably find he has been courting disaster.

Let me give an instance to illustrate this. The owner of a villa some miles north of Dublin, conceived the idea of heating two sitting-rooms on the ground floor by means of radiators heated from the kitchen-range in addition to the ordinary domestic supply. The work was put out for tender, and out of a number of estimates received the owner accepted the one he considered most advantageous, the firm whose tender was accepted being looked upon as a most respectable firm of plumbers and heating engineers (save the mark !)

The work was carried out with the usual zeal met with on contract jobs. When completed the writer had an opportunity of inspecting it, and, to the credit of master and man alike, be it said that notwithstanding the aforesaid zeal the workmanship was above the common, but unfortunately this is all that can be said in favour of the job. The attempt at heating is shown by



| | |
|---|---|
| HEAD OF WATER ON BOILER. | 13'-0' |
| LENGTH OF FLOW PIPE | 40'-0' |
| " " RETURN | 35'-0' |
| BOTTOM OF RADIATOR BELOW BOTTOM OF BOILER. ....... | 9' |
| HEIGHT OF FLOW ABOVE BOILER. | 5'-0' |
| " " RETURN. | 8'-0' |

| | |
|---|---|
| SCALE FOR DRAWING | 1" = 1-0' |
| SCALE FOR DIAGRAM. TEMPERATURE | 1/10" = 1°F |
| SCALE FOR DIAGRAM. TIME | 1/10" = 1 MIN |
| STATE OF METER AFTER EXPT | 29.063 |
| " " " BEFORE " | 28.917 |
| GAS CONSUMPTION. | 146 C.FT |
| DATE OF EXPERIMENT. | 22ND FEB 04. |

FIG. 31 (EXPERIMENTS NOS. 2 & 3).—SHOWING ARRANGEMENT OF APPARATUS.

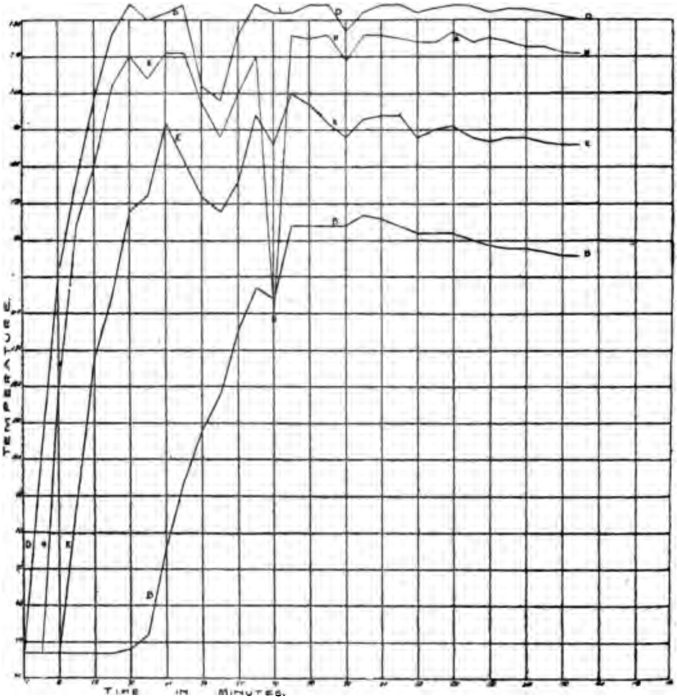


FIG. 31A (EXPERIMENTS NOS. 2 & 3).—DIAGRAM SHOWING RESULTS PLOTTED.

Fig. 32. To describe the system would be folly, to determine which is the flow and which is intended to be the return would be difficult; and to make the system more ridiculous (if such were possible), branches were left off (shown at X) with a view of heating a proposed greenhouse at some future date.

Truly a little learning is a dangerous thing, for it will be seen by the system that the originator had a notion that in order to heat below the level of the boiler the flow-pipe must be carried up a certain height, but his knowledge of heating "got air-locked" at this point. It is deplorable to think that in the year 1905 such ignorance should be met with, one might almost say under the very shadows of Technical Institutions dotted over the country, where special facilities are given to the students of plumbing to make themselves expert in all the intricacies of heating and hot-water circulation. Nor is this an isolated case, for many others could be enumerated, which display an equal amount of ignorance on the part of the designer.

The writer has been blamed, in fact he often blames himself, for saying hard things; but are they not justified? The plumber, whether he be master or man, who knowingly undertakes to carry out work about which he has not the faintest idea—save in the furnishing of the account, and in payment therefor receiving good current coin of the realm—is guilty of a grave misdemeanour which, unfortunately, is not an offence punishable by law. Yet it is an offence of such magnitude that it would task even the Mikado of Gilbert and Sullivan creation to devise a "punishment to fit the crime."

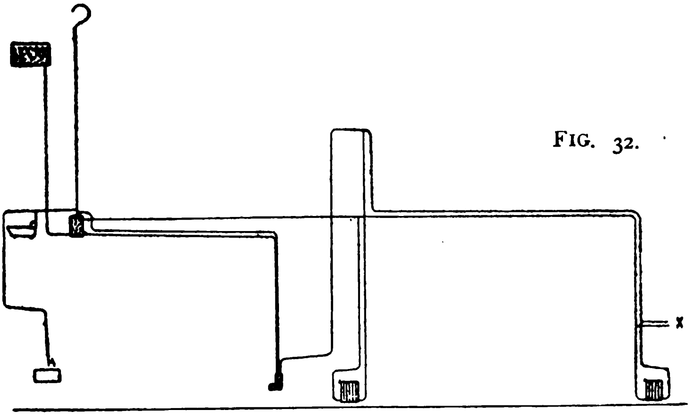


FIG. 32.

HOW NOT TO DO IT.

Yet how many such so-called plumbers do we meet with, whose chief characteristic is lack of knowledge? *These are the very men who from the pinnacle of ignorance look down upon* *technical education and spurn the idea of availing themselves of instruction, which in their lofty opinion may, in its way, be very good for boys, but is far beneath them!* Strange though it may seem, there are to-day men in connection with the trade who, if not openly antagonistic to technical instruction, refuse to avail themselves of it or allow others under their control or influence to benefit by the instruction and facilities offered in connection with Technical Schools. These men are to be found in the ranks of the masters as well as amongst the workmen.

To dwell on this would be outside the sphere of these articles, but before passing away from the subject, let me say for the benefit of all whom it may concern, that none but the silly ostrich sticks its head in a hole and feels satisfied with its false position of security, and none but the doubly ignorant refuse to learn. To this may be added, that if these members of the trade who in the past have been a clog on the wheels of progress, and know only how to fit up a stereotyped system of heating, are to maintain a position in connection with the trade, it is high time they began to study the specific gravity of water at different temperatures, and on this foundation build up a scientific knowledge of a subject which, in the past, they have taken the liberty to tinker with.

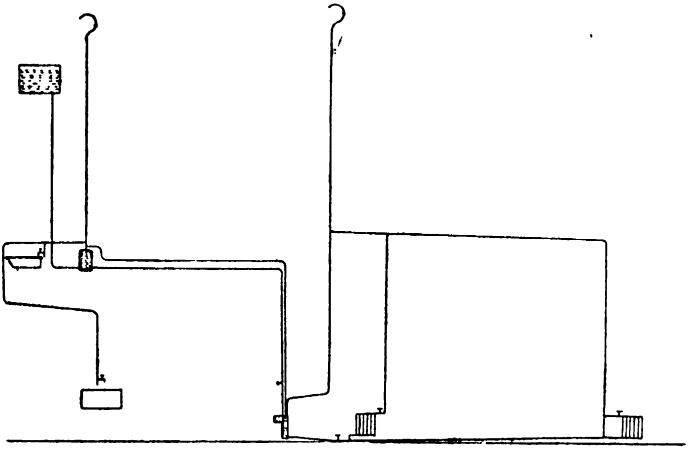


FIG. 33.

If the plumber who was responsible for the spending of the money of my friend, the villa-owner, and succeeded only in defacing the two best rooms of the house by crooked unsightly pipes, had been possessed of even an elementary knowledge of the motive power which produces hot water circulation, he would have known how to balance the return and flow circulation; so that when the particles of water in the one column become lighter—owing to expansion—they may be poised up by the heavier particles in the opposite leg of the balance.

The system might have been made a success by inverting the boiler, *i.e.* turning it upside down (which, by the way, is the best method of setting a boot boiler), and connecting the pipes as shown by Fig. 33.

### TABULATED RESULT OF EXPERIMENT NO. 2.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer D | 40 | 96 | 152 | Accident | 200 | 220 | 212 | 218 | 208 | 217 |
| ,, H | 40 | 40 | 112 | | 120 | 206 | 212 | 189 | 208 | 200 |
| ,, R | 40 | 40 | 40 | | 60 | 122 | 120 | 146 | 138 | 142 |
| ,, B | 40 | 40 | 40 | | | | Accident to B. | | | |

| Time in minutes | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer D | 212 | 217 | 208 | 208 | 220 | 198 | 174 | 216 | 213 |
| ,, H | 200 | 186 | 192 | 194 | 208 | 200 | 142 | 202 | 212 |
| ,, R | 149 | 144 | 142 | 146 | 170 | 166 | 159 | 150 | 190 |

For fluctuations of R see curves.

| Time in minutes | 95 | 100 | 105 | 110 | 115 | 120 | 125 | 130 | 135 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer D | 210 | 216 | 220 | 220 | 207 | 220 | 220 | 218 | 220 |
| ,, H | 211 | 210 | 217 | 212 | 206 | 218 | 218 | 216 | 220 |
| ,, R | 171 | 176 | 200 | 190 | 200 | 212 | 208 | 198 | 168 |

### TABULATED RESULT OF EXPERIMENT NO. 3.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer D | 47 | 100 | 150 | 176 | 198 | 216 | 224 | 220 | 222 | 224 | 202 |
| ,, H | 47 | 47 | 120 | 164 | 180 | 202 | 210 | 204 | 211 | 211 | 197 |
| ,, R | 47 | 47 | 47 | 88 | 128 | 144 | 168 | 172 | 191 | 182 | 172 |
| ,, B | 47 | 47 | 47 | 47 | 47 | 47 | 48 | 52 | 76 | 94 | 108 |

| Time in minutes | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer D | 198 | 216 | 225 | 222 | 222 | 224 | 224 | 217 | 222 | 224 | 224 |
| ,, H | 198 | 200 | 216 | 140 | 216 | 215 | 216 | 209 | 216 | 216 | 213 |
| ,, R | 168 | 176 | 194 | 186 | 200 | 197 | 192 | 188 | 193 | 199 | 194 |
| ,, B | 118 | 135 | 147 | 144 | 164 | 164 | 164 | 169 | 166 | 166 | 164 |

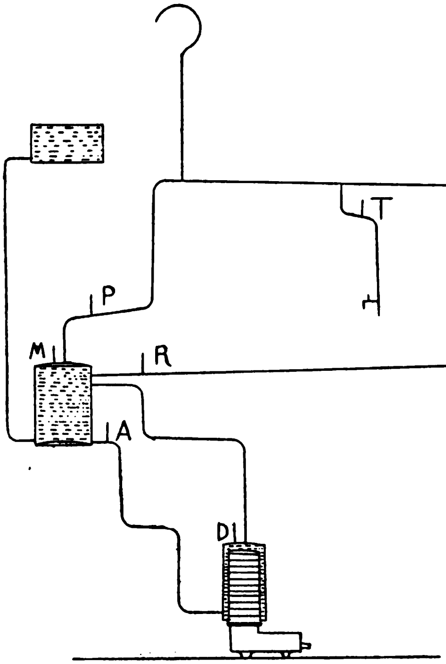
| Time in minutes | 110 | 115 | 120 | 125 | 130 | 135 | 140 | 145 | 150 | 155 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer D | 222 | 223 | 224 | 224 | 222 | 223 | 223 | 222 | 221 | 220 |
| ,, H | 214 | 214 | 217 | 214 | 215 | 214 | 213 | 213 | 211 | 211 |
| ,, R | 188 | 190 | 191 | 188 | 187 | 188 | 188 | 187 | 186 | 186 |
| ,, B | 162 | 162 | 162 | 160 | 159 | 157 | 157 | 156 | 156 | 155 |

## SECONDARY CIRCULATION.

### EXPERIMENT I.

No matter how much time we may waste in other pursuits, somehow we have a decided objection to wait on a tap delivering "hot water." It must flow immediately the tap is opened, and no time must be lost waiting for the cold water to leave the pipe before the hot comes forth.

In order to meet this demand, what is termed secondary circulation has been introduced—a loop pipe through which hot



Head of water on boiler, 11 ft.
Volume of water circulating, 26 gals.
Length of primary flow pipe, 8 ft.
Length of primary return pipe, 7 ft. 6 in.
Sizes of primary circulating pipe, ¾ in.
Length of secondary circulating pipe, 45 ft.
Size of secondary circulating pipe, 1 in.
Quantity of water drawn off at S, 20 gals.
Average temperature of water drawn off, 147 degs.
State of meter after experiment ... 32,285
State of meter before experiment ... 32,060

Gas consumption... ... ... ... 225 c. ft.

Fig. 34 (Experiment No. 1, S.C.).—Drawing Showing Arrangement of Pipes.

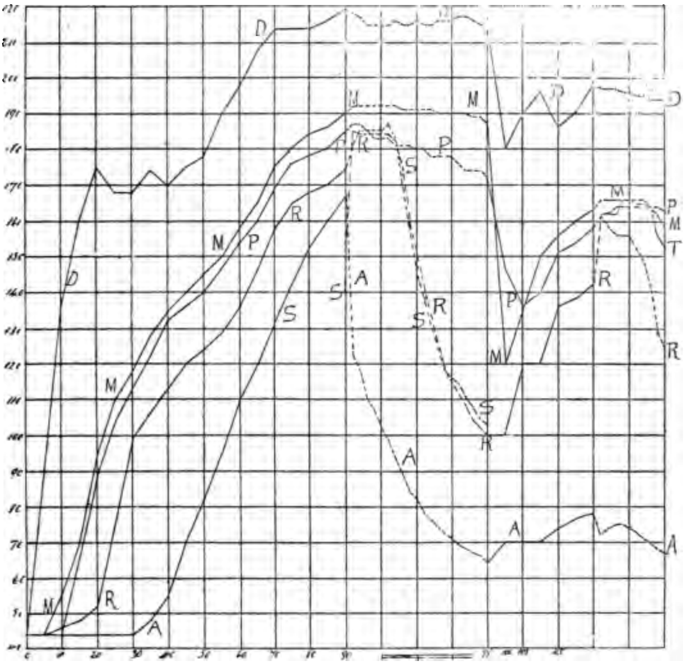


FIG. 34A (EXPERIMENT NO. 1, S.C.).—DIAGRAM SHOWING RESULTS PLOTTED.

water is continually circulating and from which all the branches are taken, so that hot water is constantly passing the branch; and when a tap is opened no time is lost waiting, a ready supply being in the vicinity of the tap.

The treatment of secondary circulation is still a disputed point, and it is questionable whether the undoubted benefits derived from secondary circulation are not often bought at too high a price. Sometimes, indeed, the success of an otherwise perfect system is sacrificed on the altar of secondary circulation, and more than one case could be mentioned where the hot water system is all but a failure owing to the cooling of the water in the secondary circulating system. The hot water is cooled in its passage through the secondary circulating pipe, and returns at such a low temperature that, on entering the cylinder, it chills the hot water coming up from the boiler.

It is generally accepted by the best authorities that the secondary return pipe should be connected to the cylinder a few inches from the top. However, the unwary sometimes return this pipe full-bore, and connect it to the bottom of the cylinder, the primary return pipe, or to the bottom of the boiler—a very natural thing to do.

The cause of all the trouble in treating this pipe is the fact that it fulfils the dual function of both a circulating and draw-off pipe. It has already been pointed out in these articles, when dealing with Experiments Nos. 13, 15 and 17, that whilst the water may circulate in one direction, immediately a tap is opened the direction of the current may be reversed.

This being so, it is a dangerous procedure to connect the secondary return to a cold stratum, for whilst the object of bringing the hot water near to the tap may be accomplished, it is very annoying to think that when the tap is opened it turns tail and allows the cold water to flow out.

It must be remembered that hot water, or, indeed, any water, flowing through pipes always acts in obedience to natural laws, and if the system is not fitted up in harmony with these laws, it cannot be expected that hot water will flow to a tap because it is indexed "Hot."

While the method of connecting the secondary return to the top of the cylinder is satisfactory, so far as the draw-off is concerned, yet the wisdom of returning comparatively cold water on top of the hot is also open to question. Indeed, the great disadvantage of secondary circulation is the loss of heat by radiation, which is aggravated when the return water is delivered like a cold douche on top of the hot.

The extent of the cooling will depend on the length, size and position of the secondary circulating pipe, which may be any length, from 20 ft. up to 200 ft. or more. When the pipe is very long, it is of necessity correspondingly large, and under such circumstances the water returns cool. To discharge such water on the top of the heated water is not a wise thing to do, although the plumber is often, through force of circumstances, compelled to fit up a system on this principle.

It is not proposed at present to deal with all the experiments conducted on secondary circulation, but rather to treat with a few of the more important ones, which it is hoped will (if not throwing any further light on the flow of water through hot water systems) at least confirm what has already been said. It would be next to impossible to fit up an experimental secondary return system of any extent in the workshop of a technical school, and it is not suggested that the systems experimented on are anything but miniature. Yet as the behaviour of water in hot water apparatus is always consistent, the results obtained will be equally applicable to a more extensive system.

The drawing, Fig. 34, shows one of the systems experimented on, and in order to simplify matters will be termed Experiment No. 1, Secondary Circulation. The primary circulating pipes were the same sizes and lengths as those of previous systems, and the secondary circulating pipe was 1 in. diameter, 45 ft. long, and returned into the cylinder 4 in. from the top and above the point where the primary flow entered. The branches were ¾ in. One branch was taken off at the high level as shown at T, 15 ft. away from the top of the cylinder. The other branch, shown at S, was taken off the centre of the secondary circulating pipe, and midway between the flow and the return legs, at the level shown on the drawing.

Space and the reader's patience will not permit me to deal with the results by *degrees*, but if the reader will compare the results of the three experiments, which are shown plotted on Figs. 34 A, 35 A, and 36 A, he will see the effect of delivering the cold return water already referred to on top of the hot water.

The difference in the distance between the curves D and M, on Figs. 34 A and 36 A, shows the loss of heat due to the mixing of the two waters, which averages over 20 degs. This loss of heat is a serious consideration, and, as already said, where the secondary circulation was very extensive the loss of heat would be much greater than that indicated by the results of these experiments.

## TABULATED RESULT OF EXPERIMENT NO. 1.—S.C.

### WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 48 | 55 |
| ,, D | 44 | 90 | 135 | 160 | 175 | 168 | 168 | 174 | 170 |
| ,, M | 44 | 44 | 55 | 70 | 95 | 110 | 118 | 128 | 135 |
| ,, P | 44 | 44 | 44 | 66 | 88 | 104 | 113 | 122 | 132 |
| ,, R | 44 | 44 | 46 | 48 | 52 | 75 | 90 | 106 | 113 |

| Time in minutes | | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer | A | 70 | 82 | 95 | 110 | 120 | 132 | 142 | 152 | 160 |
| ,, | D | 175 | 178 | 190 | 198 | 208 | 214 | 214 | 214 | 216 |
| ,, | M | 140 | 145 | 150 | 158 | 165 | 175 | 180 | 184 | 186 |
| ,, | P | 136 | 140 | 147 | 154 | 160 | 169 | 176 | 178 | 180 |
| ,, | R | 120 | 124 | 129 | 136 | 146 | 158 | 165 | 168 | 170 |

| Time in minutes | | 90 | | 95 | 100 | 105 | 110 | 115 | 120 | 125 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer | A | 167 | 1st Draw-off at S. | 64 | 70 | 70 | 70 | 74 | 77 | 78 |
| ,, | D | 219 | | 215 | 180 | 190 | 196 | 186 | 190 | 196 |
| ,, | M | 190 | | 187 | 120 | 135 | 150 | 156 | 160 | 163 |
| ,, | P | 185 | | 172 | 147 | 136 | 140 | 151 | 154 | 158 |
| ,, | R | 174 | | 100 | 100 | 120 | 120 | 134 | 138 | 142 |

WHEN DRAWING OFF AT S.

| Time in minutes | | — | — | — | 91 | — | — | — | 92 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer | A | 122 | 118 | 110 | 107 | 102 | 98 | 93 | 89 | 84 | 82 |
| ,, | D | 218 | 217 | 215 | 215 | 215 | 215 | 216 | 215 | 215 | 216 |
| ,, | M | 192 | 192 | 192 | 192 | 192 | 192 | 191 | 191 | 191 | 191 |
| ,, | P | 187 | 187 | 185 | 183 | 183 | 183 | 181 | 181 | 181 | 180 |
| ,, | R | 181 | 185 | 185 | 185 | 185 | 187 | 183 | 170 | 158 | 145 |
| ,, | S | 185 | 184 | 184 | 184 | 184 | 184 | 182 | 174 | 160 | 150 |

| Time in minutes | | — | 93 | — | — | — | 94 | — | — | — | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer | A | 78 | 76 | 74 | 73 | 71 | 69 | 68 | 67 | 66 | 64 |
| ,, | D | 215 | 215 | 215 | 216 | 216 | 217 | 217 | 216 | 215 | 215 |
| ,, | M | 191 | 190 | 190 | 190 | 190 | 190 | 190 | 189 | 189 | 187 |
| ,, | P | 180 | 178 | 178 | 178 | 178 | 176 | 174 | 174 | 174 | 172 |
| ,, | R | 138 | 131 | 124 | 118 | 115 | 111 | 108 | 104 | 102 | 100 |
| ,, | S | 141 | 132 | 126 | 118 | 116 | 114 | 110 | 108 | 105 | 103 |

WHEN DRAWING OFF AT T.

| Time in minutes | | — | — | — | 126 | — | — | — | 127 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer | A | 72 | 74 | 75 | 75 | 74 | 73 | 71 | 70 | 68 | 67 |
| ,, | D | 197 | 197 | 197 | 196 | 196 | 195 | 195 | 194 | 194 | 194 |
| ,, | M | 166 | 166 | 166 | 166 | 166 | 165 | 165 | 164 | 162 | 158 |
| ,, | P | 162 | 162 | 164 | 164 | 164 | 164 | 164 | 164 | 164 | 162 |
| ,, | R | 162 | 158 | 156 | 156 | 156 | 152 | 149 | 140 | 129 | 126 |
| ,, | T | 162 | 162 | 162 | 166 | 166 | 166 | 166 | 164 | 156 | 152 |

| Time in minutes | | — | 128 | -- | — | — | 129 | — | — | — | 128 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer | A | 65 | 65 | 65 | 62 | 62 | 61 | 60 | 59 | 59 | 58 |
| ,, | D | 193 | 193 | 192 | 191 | 192 | 191 | 191 | 190 | 190 | 190 |
| ,, | M | 148 | 127 | 116 | 107 | 98 | 87 | 87 | 84 | 81 | 79 |
| ,, | P | 162 | 151 | 136 | 124 | 113 | 100 | 93 | 90 | 86 | 82 |
| ,, | R | 122 | 118 | 115 | 113 | 110 | 108 | 104 | 102 | 100 | 98 |
| ,, | T | 148 | 134 | 122 | 108 | 102 | 99 | 90 | 84 | 82 | 82 |

## EXPERIMENT II.

Fig. 35A shows how this could be minimised to a certain extent. The apparatus is shown by Fig. 35, and, as will be seen, was exactly similar to that employed in Experiment No. 1, except that the secondary return pipe was connected to the cylinder

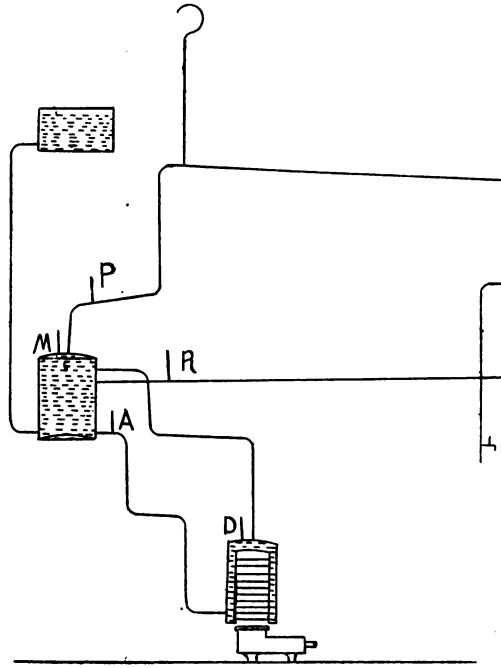


FIG. 35 (EXPERIMENT 2, S.C.).—DRAWING SHOWING ARRANGEMENT OF PIPES.

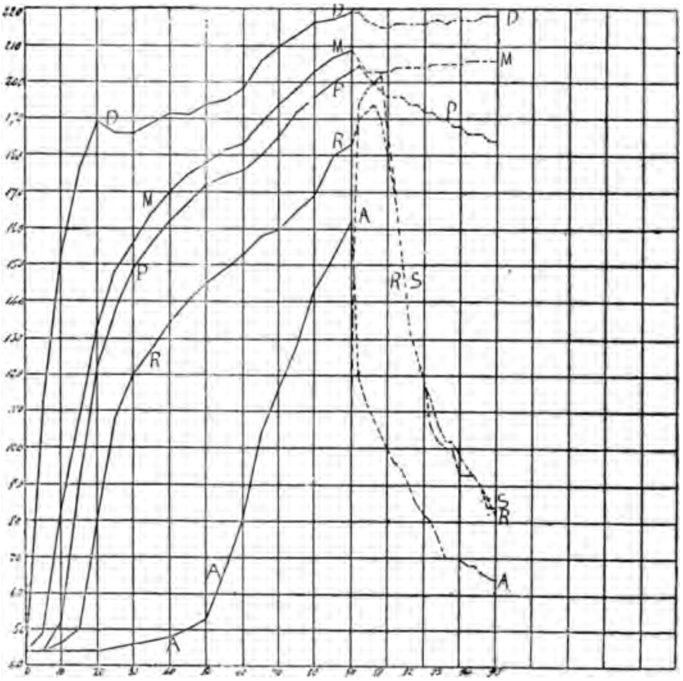


FIG. 35A (EXPERIMENT 2, S.C.).—DIAGRAM SHOWING RESULTS PLOTTED.

below the point where the primary flow entered; in fact, the couplings were interchangeable, and the return was connected to the flow, and *vice versâ*, so that the return water entered the cylinder below the hot coming up from the boiler.

But if this method of connecting the pipes had the effect of apparently reducing the cooling process, it had a bad effect on the draw-off, as will be seen by comparing the two sets of dotted curves, Figs. 34A and 35A, which represent the travel of the thermometers during the time the tap was open.

It will be seen that all the water drawn off travelled through the return leg of the secondary circulating pipe, and that not one drop travelled by way of the flow; indeed it is safe to assume that the water had a tendency to return to the cylinder through the flow pipe during the time the tap was open. But this is one of the many points which must be left to the reader to study out; sufficient to say that what happened during the draw-off in the case of Experiments Nos. 13, 15, and 17, again happened during the draw-off in the experiments now being studied. The direction of the flow of water was reversed immediately the tap was opened, the water travelling the most direct route to the branch, which invariably happens.

When the tap T was opened (Experiment No. 1), we see by the tabulated results that the water flowed to the branch in both directions, a fact which has already been dealt with when treating Experiments Nos. 13 and 17, the present results confirming those obtained previously.

This proves that it is no advantage to connect the secondary return to the cylinder below the point where the primary flow enters, but rather the contrary. The water cools in its passage through the secondary system all the same, and when a tap is opened, water is drawn from the cold stratum, depending of course on the position of the branch and other circumstances.

## TABULATED RESULT OF EXPERIMENT NO. 2.—S.C.

### WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 44 | 44 | 44 | 44 | 44 | 45 | 46 | 47 | 48 | 50 |
| ,, D | 44 | 112 | 152 | 177 | 189 | 186 | 186 | 189 | 191 | 191 |
| ,, M | 44 | 49 | 82 | 108 | 133 | 148 | 156 | 164 | 170 | 175 |
| ,, P | 44 | 44 | 52 | 93 | 122 | 138 | 149 | 156 | 162 | 167 |
| ,, R | 44 | 44 | 46 | 50 | 80 | 108 | 120 | 127 | 134 | 140 |

| Time in minutes | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | Draw-off at S |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermometer A | 53 | 66 | 81 | 104 | 116 | 129 | 143 | 152 | 162 | |
| ,, D | 194 | 195 | 198 | 206 | 210 | 213 | 216 | 217 | 119 | |
| ,, M | 178 | 181 | 183 | 189 | 194 | 198 | 203 | 207 | 209 | |
| ,, P | 171 | 174 | 176 | 180 | 185 | 192 | 196 | 200 | 203 | |
| ,, R | 145 | 149 | 153 | 158 | 160 | 165 | 169 | 180 | 183 | |

### WHEN DRAWING OFF AT S.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time in minutes | — | — | — | 91 | — | — | — | 92 | — | — |
| Gallons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer A | 120 | 113 | 109 | 104 | 100 | 96 | 94 | 90 | 85 | 82 |
| ,, D | 219 | 217 | 216 | 215 | 215 | 216 | 216 | 216 | 216 | 216 |
| ,, M | 206 | 203 | 203 | 203 | 203 | 204 | 204 | 204 | 204 | 204 |
| ,, P | 205 | 202 | 200 | 198 | 196 | 196 | 196 | 194 | 194 | 192 |
| ,, R | 190 | 192 | 194 | 190 | 180 | 167 | 151 | 132 | 126 | 118 |
| ,, S | 194 | 198 | 200 | 202 | 187 | 167 | 149 | 134 | 126 | 115 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time in minutes | — | 93 | — | — | — | 94 | — | — | — | 95 |
| Gallons | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer A | 80 | 76 | 70 | 70 | 70 | 68 | 68 | 66 | 65 | 64 |
| ,, D | 217 | 217 | 216 | 217 | 217 | 217 | 217 | 218 | 218 | 218 |
| ,, M | 205 | 205 | 205 | 205 | 206 | 206 | 206 | 206 | 206 | 206 |
| ,, P | 192 | 190 | 190 | 188 | 188 | 186 | 186 | 186 | 184 | 184 |
| ,, R | 113 | 106 | 102 | 102 | 98 | 95 | 92 | 90 | 86 | 82 |
| ,, S | 110 | 102 | 100 | 100 | 93 | 93 | 93 | 90 | 84 | 84 |

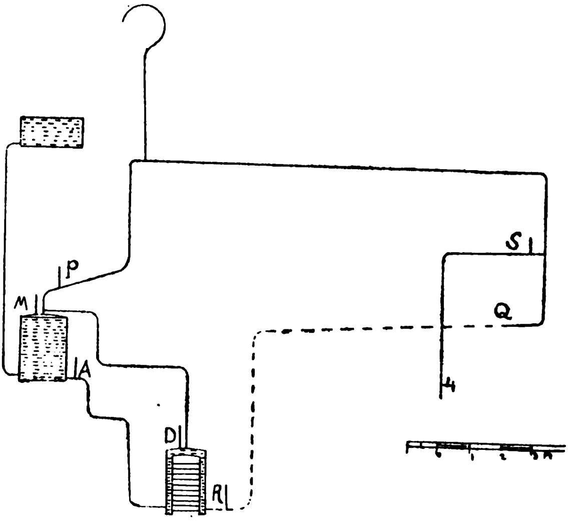
## EXPERIMENT III.

The next system experimented on was exactly similar to the two previous ones, except that the primary flow was connected to the extreme top of the cylinder, and the secondary return pipe was reduced to $\frac{3}{8}$ in. (after it passed to the branch S), and connected to the boiler, as shown by the dotted line Fig. 36; the length of 1 inch secondary circulating pipe being 30 feet, and the length of $\frac{3}{8}$ inch being 15 feet.

The results obtained are shown by the plotted diagram Fig. 36A, from which it will be seen that the mixing which took place at the top of the cylinder during the heating period of the last two experiments was avoided; and as the water in the secondary system circulated much slower, less heat was lost, with the result that at the end of 90 minutes the water in the system was at a much higher temperature than that registered by the thermometers at the corresponding period in the previous experiments.

This point is very forcibly illustrated by the curves, on comparing the several results, as is also the fact that the water in the secondary circulating pipe was hotter—notwithstanding that the return was reduced to $\frac{3}{8}$ inch—in the latter experiment than in the case of the two former ones when the pipe was returned full-bore into the cylinder.

On turning to the curves representing the draw-off, we see that the water was drawn off at a much higher temperature in the present experiment, and that while some of the water travelled to the branch through the $\frac{3}{8}$ inch pipe past R and Q, by far the greater portion went by way of the flow pipe past P, as curve S, which represents the water drawn off, occupies a position close to P and M; this going to prove that the major portion of water drawn off was supplied from the top of the cylinder.



Head of water on boiler, 11 ft.
Volume of water circulating, 26 gals.
Length of primary flow pipe, 8 ft.
Length of primary return pipe, 7 ft. 6 in.
Size of primary circulating pipe, ¾ in.
Length of secondary circulating pipe, 45 ft.
Size of secondary circulating pipe, 1 in. reduced to ⅜ in.
Quantity of water drawn off, 20 gals.
Average temperature of water drawn off, 182 degs.
State of meter after experiment ... 33,020
State of meter before experiment ... 32,830

Gas consumption ... ... ... ... 190 c. ft.

FIG. 36 (EXPERIMENT NO. 3 S.C.).—DRAWING SHOWING ARRANGEMENT OF APPARATUS.

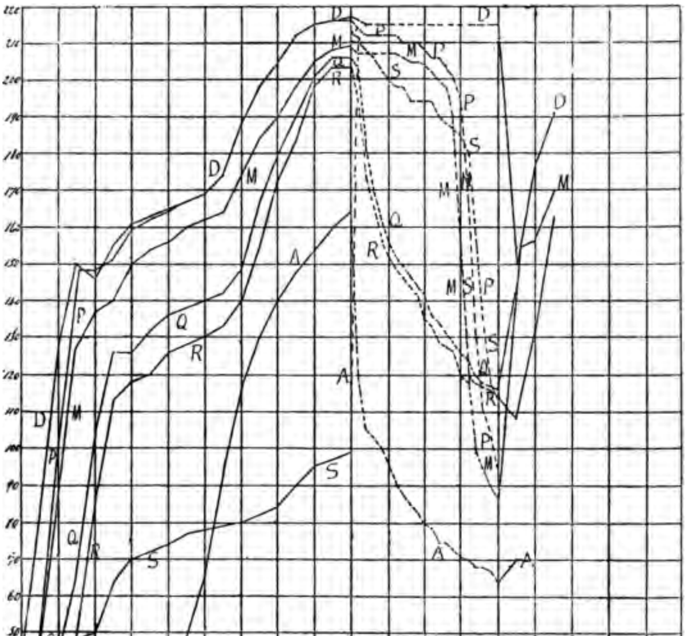


FIG. 36A (EXPERIMENT NO. 3, S.C.).—DIAGRAM SHOWING RESULTS PLOTTED.

The results obtained during the heating period, and also during the period of the draw-off, place this method of treating secondary circulation in the front rank of the different systems adopted.

The writer is well aware how this statement will be received by many men who are honourably connected with the trade, who have all their lives been engaged in this work, and are well qualified to pass judgment. However, it is only made after careful study and exhaustive experimental research. I have no hesitation in saying that where economy counts for anything, and where a speedy and liberal supply of hot water is required, there is no better method of connecting a system than the one of connecting the primary flow to the top of the cylinder, reducing the secondary return to at least $\frac{3}{8}$ inch after it passes the last branch, and connecting it to the primary return, the bottom of the cylinder, or the bottom of the boiler, as shown by Fig. 36.

There is much in this connection that must be left unsaid, and the writer will in the next give the results of experiments on the cylinder and tank system, which will be the last of the present series.

Average temperature of the water drawn off *in the three previous experiments:—*

| No. of Experiment. (Secondary circulation) | Average temperature of water drawn off. |
|---|---|
| No. 1 ... ... ... ... | 147 degrees. |
| No. 2 ... ... ... ... | 130 „ |
| No. 3 ... ... ... ... | 182 „ |

TABULATED RESULT OF EXPERIMENT NO. 3.—S.C.

WHEN CIRCULATING.

| Time in minutes | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 |
|---|---|---|---|---|---|---|---|---|
| Thermometer A | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| ,, D | 44 | 83 | 128 | 150 | 146 | 155 | 161 | 163 |
| ,, M | 44 | 46 | 88 | 127 | 137 | 140 | 150 | 154 |
| ,, P | 44 | 48 | 100 | 149 | 149 | 151 | 160 | 162 |
| ,, R | 44 | 44 | 44 | 46 | 86 | 113 | 118 | 120 |
| ,, Q | 44 | 44 | 44 | 64 | 104 | 126 | 126 | 132 |
| ,, S | 44 | 44 | 46 | 48 | 50 | 64 | 70 | 72 |

| Time in minutes | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 |
|---|---|---|---|---|---|---|---|---|
| Thermometer A | 45 | 48 | 66 | 94 | 117 | 130 | 140 | 148 |
| ,, D | 165 | 167 | 169 | 174 | 188 | 198 | 205 | 212 |
| ,, M | 156 | 160 | 162 | 164 | 174 | 184 | 190 | 198 |
| ,, P | 164 | 167 | 169 | 172 | 187 | 198 | 205 | 212 |
| ,, R | 126 | 128 | 130 | 133 | 140 | 156 | 172 | 183 |
| ,, Q | 136 | 138 | 140 | 142 | 149 | 167 | 180 | 190 |
| ,, S | 74 | 77 | 78 | 79 | 80 | 82 | 84 | 90 |

| Time in minutes | | 80 | 85 | 90 | | 95 | 100 | 105 | 110 |
|---|---|---|---|---|---|---|---|---|---|
| Thermometer | A | 154 | 160 | 164 | Draw-off at S | 64 | 70 | 70 | 70 |
| ,, | D | 215 | 216 | 216 | | 215 | 150 | 177 | 191 |
| ,, | M | 205 | 208 | 209 | | 87 | 155 | 156 | 170 |
| ,, | P | 214 | 216 | 216 | | 95 | 154 | 167 | 187 |
| ,, | R | 198 | 203 | 203 | | 114 | 108 | 133 | 163 |
| ,, | Q | 201 | 206 | 206 | | 116 | 145 | 167 | 171 |
| ,, | S | 95 | 97 | 99 | | 113 | — | — | — |

WHEN DRAWING OFF AT S.

| Time in minutes | | — | — | — | 91 | — | — | — | 92 | — | — |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thermometer | A | 120 | 105 | 103 | 100 | 96 | 91 | 88 | 85 | 83 | 80 |
| ,, | D | 216 | 215 | 215 | 215 | 215 | 215 | 215 | 215 | 215 | 215 |
| ,, | M | 207 | 207 | 207 | 207 | 207 | 207 | 206 | 206 | 205 | 204 |
| ,, | P | 214 | 212 | 212 | 212 | 212 | 212 | 210 | 210 | 210 | 208 |
| ,, | R | 193 | 174 | 167 | 156 | 152 | 149 | 147 | 146 | 144 | 135 |
| ,, | Q | 203 | 183 | 170 | 162 | 156 | 152 | 150 | 147 | 144 | 142 |
| ,, | S | 210 | 208 | 206 | 202 | 200 | 198 | 198 | 194 | 194 | 194 |

| Time in minutes | | — | 93 | — | — | — | 94 | — | — | — | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gallons | | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Thermometer | A | 79 | 75 | 75 | 73 | 71 | 70 | 68 | 68 | 67 | 64 |
| ,, | D | 215 | 215 | 215 | 215 | 215 | 215 | 215 | 215 | 215 | 215 |
| ,, | M | 202 | 200 | 198 | 190 | 158 | 120 | 99 | 95 | 90 | 87 |
| ,, | P | 206 | 206 | 203 | 201 | 194 | 167 | 131 | 111 | 104 | 95 |
| ,, | R | 133 | 129 | 127 | 127 | 120 | 118 | 118 | 118 | 116 | 114 |
| ,, | Q | 136 | 134 | 131 | 129 | 126 | 124 | 120 | 118 | 117 | 116 |
| ,, | S | 194 | 190 | 188 | 187 | 185 | 180 | 158 | 135 | 118 | 113 |

## CYLINDER AND TANK SYSTEMS.

### EXPERIMENTS I. & II.

To return to Experiments Nos. 1 and 2 conducted at the outset of this series on the so-called cylinder and tank systems.

The apparatus is shown by Fig. 37. It will be seen that the boiler was the steam jacket, already described and shown on Fig. 3. This boiler was not capable of heating the cylinder and tank, and whilst the results are of little or no practical value, still they present one or two interesting points worthy of notice.

For instance, curve A, Fig. 37 A, shows that the temperature at that point fell two degrees after heat was applied. The apparatus had been filled some time before the commencement of the experiment, and the fall in temperature thus indicated was no doubt due to the water in the core being at a lower temperature than that at the walls of the cylinder. When the water commenced to circulate, the cold water from the inner core, in registering its passage past A, caused that thermometer to fall, and, as will be seen by the curve, this water was two degrees colder than the water that passed this point prior to the 10 minutes reading. This is a very fine point, but tends to illustrate the fact that water is a bad conductor of heat.

Another point worth noting is the direction of the flow of the water. It will be observed that the water could circulate in either of two directions. It could travel to the cylinder past H, or it could flow direct to the tank viâ P—the most direct way to the top of the system. However, when heat was applied it was found that the water circulated to the cylinder, and hence to the tank by way of N. The reason for this will be found on studying the apparatus. It will be seen that the branch leading to the cylinder was fixed in a vertical direction, whereas the pipe leading to the tank was carried horizontally for a certain distance. When the water commenced to circulate, the heated particles which were poised up from the boiler took the first opportunity of ascent, just ascending as pieces of cork would do.

This is a very important point to keep in mind when arranging branches for heating, for had the tee leading to H been horizontal, there is no doubt that the direction of the flow would have been by way of P direct to the tank. This, in fact, occurred in some other experiments.

In Experiment No. 2 the pipe from the top of the tank was connected to the bottom of the boiler, as shown by the dotted lines Fig. 37. This connection did not alter the result, which was practically the same as result No. 1.

Before proceeding to deal with the results of further experiments conducted on systems of a more practical character than the two preceding ones, let us review the history of the introduction of the combined cylinder and tank arrangement.

The old tank system which consisted of a boiler and tank—the latter being usually situated above the highest fitting to be supplied with hot water, and the branches taken off the flow pipe—was found to be defective, inasmuch as it was possible to empty the tank of water, thereby risking the safety of the boiler. To overcome this difficulty the cylinder system was adopted, and as the cylinder is situated convenient to the boiler, and the branches taken off the top of the cylinder, it is not possible to empty the cylinder of water.

Notwithstanding this advantage, the adoption of the cylinder system introduced another defect, for it was found that hot water taps situated on a high level were supplied with only a very limited quantity of water, the water had to travel down through the cold supply pipe to the cylinder, and up the secondary circulating pipe to perhaps the third or fourth floor of the building, and through the branch pipe, before reaching the tap. The flow of water to the tap was thus retarded by friction, as the water had to pass through long lengths of pipe.

In order to counteract the disadvantages of one system by the merits of the other, a combined system of cylinder and tank arrangement was introduced. The cylinder, being situated convenient to the boiler, and no branches being taken off the primary

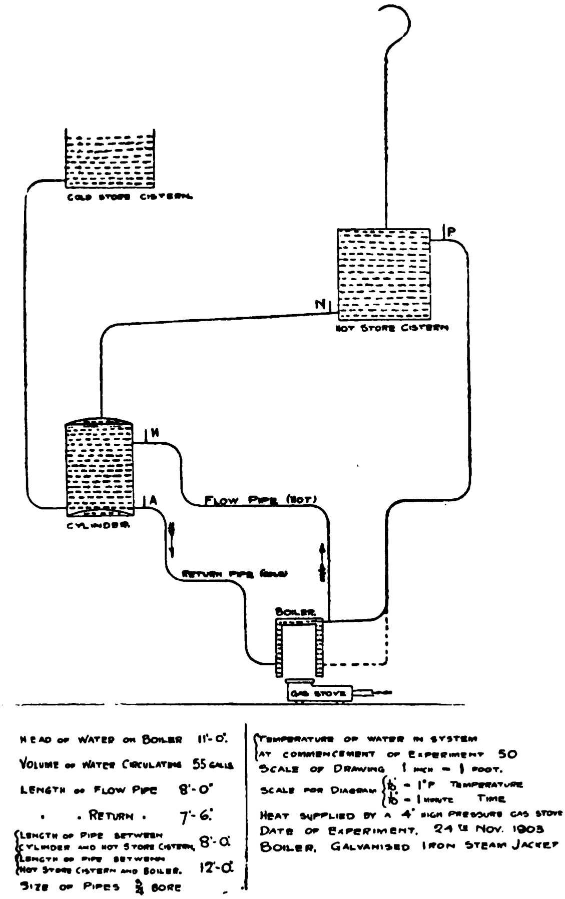

COLD STORE CISTERN
P
N
HOT STORE CISTERN
H
CYLINDER
A
FLOW PIPE (HOT)
RETURN PIPE (COLD)
BOILER
GAS STOVE
HEAD OF WATER ON BOILER 11'-0".
VOLUME OF WATER CIRCULATING 55 GALLS
LENGTH OF FLOW PIPE 8'-0"
" " RETURN " 7'-6".
LENGTH OF PIPE BETWEEN CYLINDER AND HOT STORE CISTERN, 8'-0".
LENGTH OF PIPE BETWEEN HOT STORE CISTERN AND BOILER. 12'-0".
SIZE OF PIPES ¾ BORE
TEMPERATURE OF WATER IN SYSTEM AT COMMENCEMENT OF EXPERIMENT 50
SCALE OF DRAWING 1 INCH = 1 FOOT.
SCALE FOR DIAGRAM 1/10" = 1°F TEMPERATURE
1/10" = 1 MINUTE TIME
HEAT SUPPLIED BY A 4" HIGH PRESSURE GAS STOVE
DATE OF EXPERIMENT. 24TH NOV. 1903
BOILER. GALVANISED IRON STEAM JACKET

FIG. 37 (EXPERIMENTS NOS. 1 & 2).—SHOWING ARRANGEMENT OF APPARATUS.

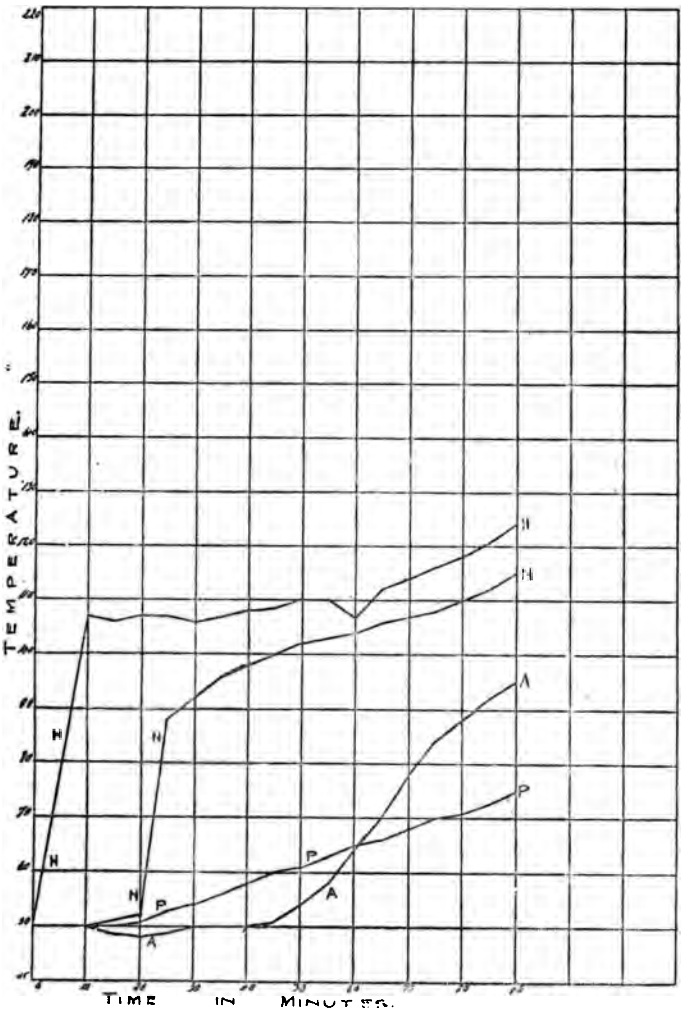


FIG. 37A (EXPERIMENTS NOS. 1 & 2).—DIAGRAM SHOWING RESULTS PLOTTED.

circulating pipes, it cannot be emptied by any of the draw-off branches on the system. The tank is situated above the highest fitting, for the purpose of supplying the taps on the high level with water.

There could be no more feasible idea than having a store of hot water above the highest fitting, ready to deliver itself when the tap is opened; but it is safe to assume that many cylinder and tank systems are not designed to ensure the maximum output of hot water. Indeed, one often meets with a combined system where the addition of the tank is simply a third wheel to the cart, and there can be little doubt that its removal would give better results, including a great saving of labour to the boiler.

The student of these articles will be aware that head-pressure, friction, and specific gravity control the flow of water to a hot water tap. The combined system presents many opportunities of introducingf defects, and is a pitfall to a great many unwary members o the trade. It is not enough for the plumber to know that he saw some such system recommended in a standard work on the subject, no more than it is sufficient grounds for adopting a system because of the good results obtained from such an arrangement in the present series of experiments. Very often local circumstances make a standard system impossible, and, if adopted it proves a failure.

What is wanted is a sound, scientific knowledge of the subject on the part of those who practice in this class of work, in order that they may be able to apply such knowledge to overcome all difficulties, and designing a system adapted to the circumstances of each case, consistent with the coal consumption, the supply of hot water required, and the numerous other points which present themselves from time to time.

On studying the system shown by Fig. 38 (which will be recognised as one generally recommended), one must have grave doubts regarding its capability to deliver the maximum quantity of hot water. So far as the heating of the water is concerned, the system embodies many defects, for the mixing spoken of in the previous chapter dealing with secondary circulation is increased one hundredfold, and requires excessive boiler capacity and excessive firing to counteract. Apart from the defects in this direction, there is a possibility that the water stored in the hot tank cannot even be drawn off when it is heated.

Let us consider the system and the conditions which exist before and after a tap is opened.

When the apparatus is full of water and the fire is lighted, the hot water works up into the tank, which forms a storage ready to supply the bath when the tap is opened. For the sake of argument let it be supposed that the cold store cistern is situated 7 ft. above the hot water tank, and 14 ft. above tap No. 1. This 14 ft. will exert a pressure of 6 lbs.

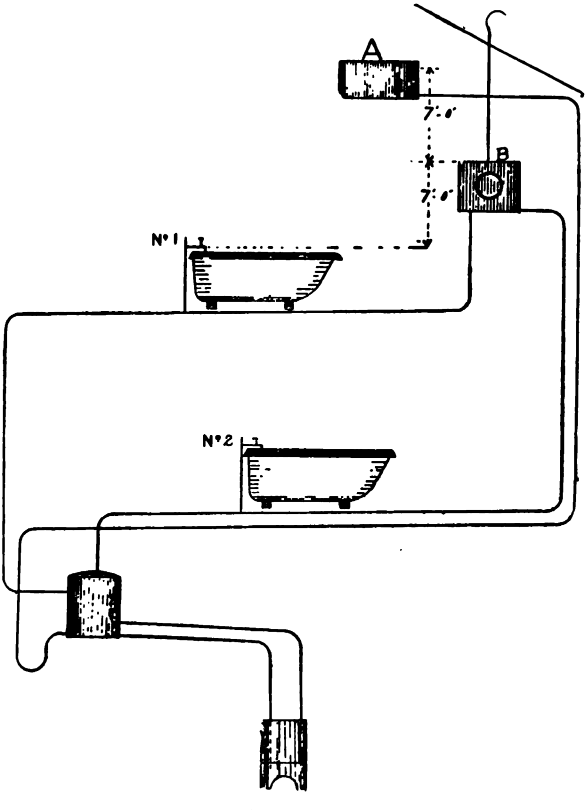
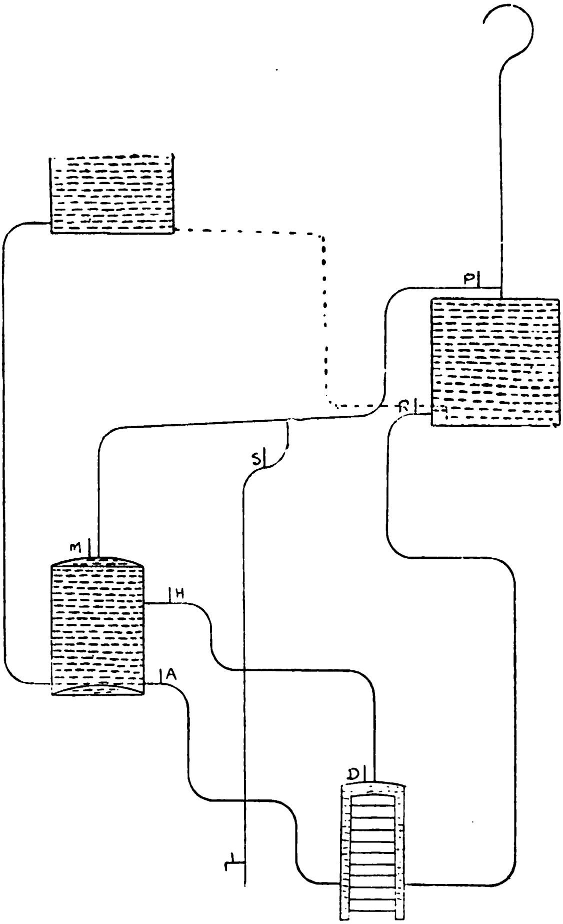


Fig. 38.



HEAD OF WATER ON BOILER. 11'-0"
LENGTH OF PRIMARY FLOW PIPE 8'-0"
" " " RETURN " 7'-6"
" " SECONDARY FLOW " 14'-0"
" " " RETURN " 12'-0"
SIZE OF PIPES. $\frac{3}{4}''$.
VOLUME OF WATER CIRCULATING. 56 GALLS.
AMOUNT " " DRAWN OFF 24 "
AVERAGE TEMPERATURE OF FIRST 20 GALLONS DRAWN OFF. . . . 136°F.
TEMPERATURE OF WATER AT COMMENCEMENT OF EXPERIMENT. . . . 47°F.
SCALE FOR DRAWING 1" = 1'-0"

SCALE FOR GALLONS. $\frac{1}{3}''$ = 1 GALL
SCALE FOR DIAGRAM
- TEMPERATURE $\frac{1}{10}''$ = 1°F
- TIME
  - WHEN SYSTEM CIRCULATING. $\frac{1}{10}''$ = 1 MIN
  - DURING DRAW OFF $\frac{4}{5}''$ = 1 MIN

HEAT SUPPLIED BY 8" H.P. GAS STOVE
RATE OF DRAW OFF, 4 GALLS PER MIN
STATE OF METER AFTER EXPERT 29,676
" " " BEFORE " 29,485
GAS CONSUMPTION. 191 C.FEET
DATE OF EXPERIMENT 26TH FEB '04

FIG. 39 (EXPERIMENT NO. 3).—SHOWING ARRANGEMENT OF APPARATUS.

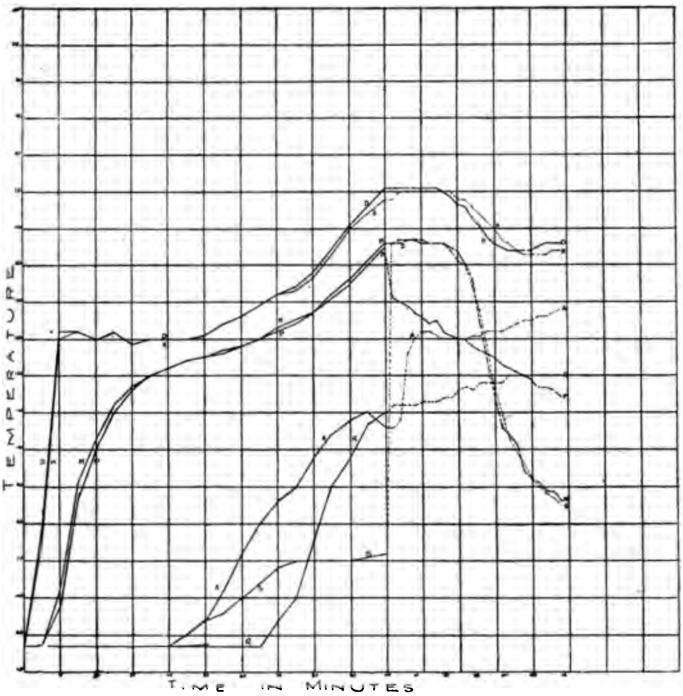


FIG. 39A (EXPERIMENT NO. 3).—DIAGRAM SHOWING RESULTS PLOTTED.

on the tap. The water in the tank will be under 3 lbs. pressure, but, mark you, this pressure is not transmitted from the cold cistern—because for all practical purposes the hot tank is an open vessel—but rather this 3 lbs. pressure is due to the water standing up 7 ft. in the expansion-pipe, finding the same level as the water in the cold cistern. Hence, when the tap is shut, it is subject to an equal pressure of 6 lbs. transmitted from these two sources; but immediately the tap is opened, the level of the water in the expansion-pipe lowers, consequently the pressure on the tank is reduced 3 lbs.

At this period there are two available sources of supply—the hot tank and cold cistern, which we will term A and B (see Fig. 38). B is exerting 3 lbs. pressure on the tap, whereas A is exerting 6 lbs. pressure, so that there are two unequal pressures contending for the outlet. A has also a greater specific gravity than B, and there can be little doubt that A would control the output of water but for the third factor — friction—which comes into play. Thus, while A has the advantage of head-pressure and specific gravity, it has to contend with friction. This cannot be estimated with any degree of accuracy, as there is such a variety of circumstances connected with hot water systems as regards the size and length of cold supply, circulating, and branch pipes, bends and other obstructions, taps, connections, &c. However, we must take into account the fact that the cold supply and circulating pipes are usually of a much larger area than the orifice of the tap. Therefore, 3 lbs. pressure would be a considerable factor under such circumstances, and capable of overcoming a certain amount of friction.

Viewing the system from this standpoint, it will readily be seen that in a system connected on this principle there is a danger that the hot water stored in the tank may not possess the necessary energy to enable it to deliver itself at the tap. This being so there should be a certain amount of caution and judgment employed in fixing the position of the tank, cylinder or cistern, as well as in arranging the size and positions of the various pipes.

In order to properly conduct an experiment on the cylinder and tank system, it would be necessary to have an available four-story building, or its equivalent. As this was not available when these experiments were conducted, the results must be taken for what they are worth, considering that the tanks, cylinder, &c. were in such close proximity.

## EXPERIMENT III.

The apparatus is shown by Fig. 39, from which it will be seen that the secondary flow entered the extreme top of the tank and that the secondary return was connected to the boiler. It is not droposed at this advanced stage to treat in detail the results obtained, for such would be wearisome to reader and writer alike, but rather to deal in a general way with what happened during the heating and draw-off periods.

So far as heating the water is concerned, the system shown by Fig. 39 presents perhaps one of the best methods that could be adopted, except, indeed, that the writer would be inclined to connect the primary flow to the top of the cylinder, and thus do away altogether with mixing hot and colder water. A glance at the dotted curves, Fig. 39A, will show that this would be a very defective system to adopt in practice, as the hot water in the tank cannot be drawn off *direct.*

A great improvement on this system would be to connect the cold supply to the bottom of the tank, turning it in a downward direction, as shown by the dotted lines, Fig. 39.

## EXPERIMENT IV.

The next experiment was on a system which is perhaps more generally adopted than any other.

The apparatus employed is shown by Fig. 40, and it will be seen that the two secondary circulating pipes are connected to the bottom of the tank, the return re-entering the cylinder a few inches from the top, a method very often recommended, and one, indeed, that is generally practised.

After the remarks on secondary circulation it will be unnecessary to treat the heating period, as the same notes apply; but it is well to notice the effect of the cooling or mixing which took place at the top of the cylinder, and indicated by the solid curves. It will be observed that the water short-circuited through the primary circulating pipes between the cylinder and the boiler.

This point is well worthy of special study, as it proves the fallacy of the idea that "hot water" rises to the top, which is responsible for a great many mistakes committed in connection with heating and hot water supply. Hot water rises to the top when it is poised up by some heavier body, such as colder water; and if in a hot water system—as, for example, the one we are now studying—the hot and cold water are brought into conflict, it tends to destroy the motive power on which we rely to produce circulation. Therefore the flow of water, and consequently the heating of the water in the tanks, will be marred, and the results cannot be so satisfactory as if the system was connected on what may be termed the "balance principle."

To turn to the period of the draw-off, we see by the dotted curves, Fig. 40A, that the water in the tank was not drawn off, and also that the water travelled to the branch in two directions: From the top of the cylinder, and a minor quantity through the secondary return pipe, past R, across the bottom of the tank, and hence to the branch *viâ* P. The tank being fitted with a glass

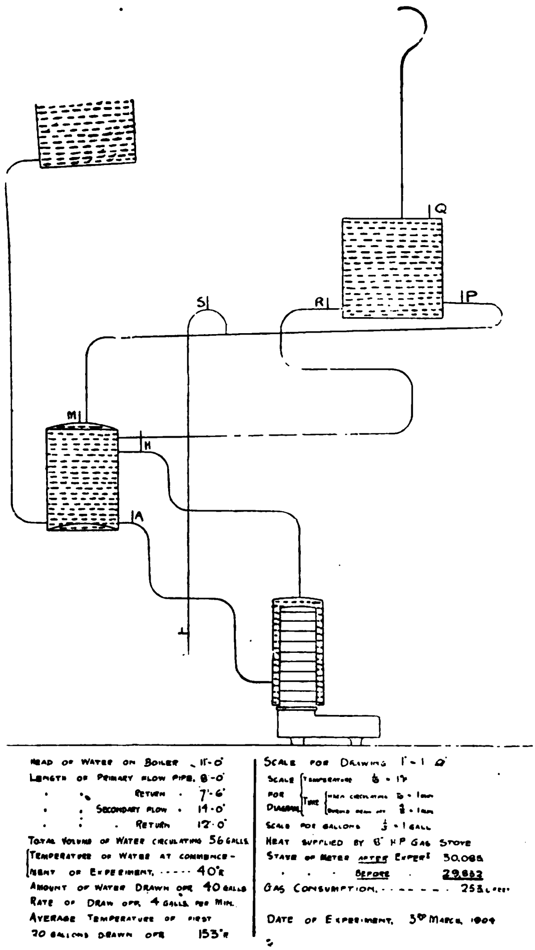

Q
P
R
S
M
H
A
Head of Water on Boiler 11'-0"
Length of Primary flow pipe. 8'-0"
" " Return 7'-6"
" " Secondary flow 14'-0"
" " " Return 12'-0"
Total Volume of Water circulating 56 Galls.
Temperature of Water at commencement of Experiment. 40°F
Amount of Water Drawn off 40 Galls.
Rate of Draw off 4 Galls. per Min.
Average Temperature of first 20 gallons drawn off 153°F
Scale for Drawing 1" = 1' 0"
Scale for Diagram Temperature
Time When circulating = 1 min
During draw off = 1 min
Scale for gallons = 1 Gall.
Heat supplied by 8" H P Gas Stove
State of Meter after Expert. 30,085
" " " Before 29,832
Gas Consumption 253 c. feet
Date of Experiment, 5th March, 1904

FIG. 40 (EXPERIMENT NO. 4).—DRAWING SHOWING ARRANGEMENT OF APPARATUS.

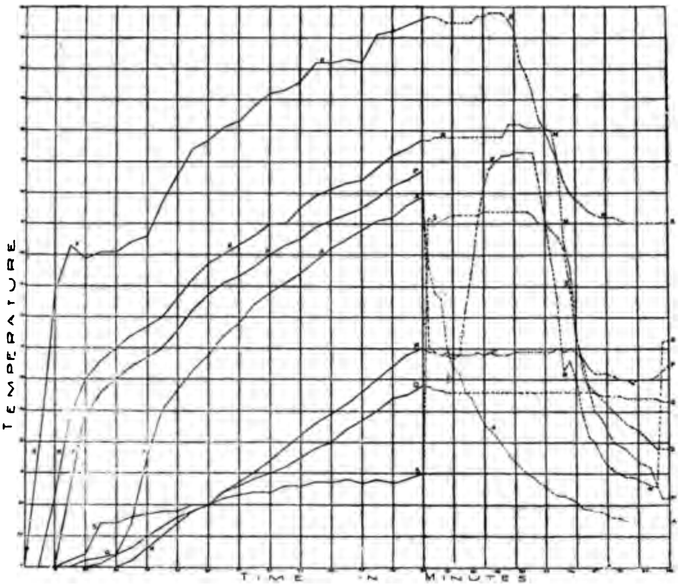


FIG. 40A (EXPERIMENT NO. 4).—DIAGRAM SHOWING RESULTS PLOTTED.

gauge the level of the water in the tank could be watched. It was observed that during the draw-off the water in the tank only lowered a few inches, and at the end of the draw-off—40 gallons —the water had only lowered 3 in. In other words, 40 gallons in all were drawn off; 37 gallons flowed from the cylinder, and only 3 gallons were drawn from the tank.

This system did not give satisfaction during the heating period, nor yet when water was being drawn off. The water in the tank did not heat satisfactorily for reasons already explained, and even if the tank had contained hot water, it could not have been drawn off by a branch taken off the secondary circulating pipe.

Several experiments were conducted on systems connected on the same principle, and the same results were obtained on every occasion. In some of the later experiments a very powerful coil boiler was employed; but while the water in the system appeared to heat satisfactorily, the thermometers showed that the water in the cylinder was much hotter than the water in the tank, and that the circulation to the tank was sluggish.

It might appear at first sight that friction due to the small bore pipe was the cause of this, but this was not so; for when the secondary flow was connected to the top of the tank, and the secondary return connected to a cold strata, both the tank and cylinder heated well. It may be added that when the coil boiler heated by a coke fire was employed the system shown by Fig. 40 yielded a very fair supply of hot water, but this did not alter the fact that the store of hot water in the tank remained untapped.

There is just a possibility that some of the systems which give more or less satisfaction owe their success to the boiler and fire employed. At the same time, if a system embodies the defects just mentioned, even though it may be capable of supplying a certain amount of hot water, yet the cost of production must be far in excess of the yield. The best results were obtained when the cold supply was connected to the tank, as shown by dotted line, Fig. 39.

Fig. 41 shows the arrangement of the pipes in another experiment conducted on the cylinder and tank arrangement. It will be seen that the system is somewhat similar to that shown by Fig. 39, the only difference being that the primary flow pipe was connected to the extreme top of the cylinder and the cold supply pipe connected to the bottom of the tank. The primary circulating pipes were 1 inch diameter and the secondary circulating and other pipes were ¾ inch diameter.

At first sight one might think that with such an arrangement of pipes the hot water would pass the cylinder and circulate direct to the tank, leaving the cylinder comparatively cold; but this did not occur, for as will be seen by the curves, the heat was evenly distributed between the cylinder and the tank. The results therefore support what has already been said, viz., that

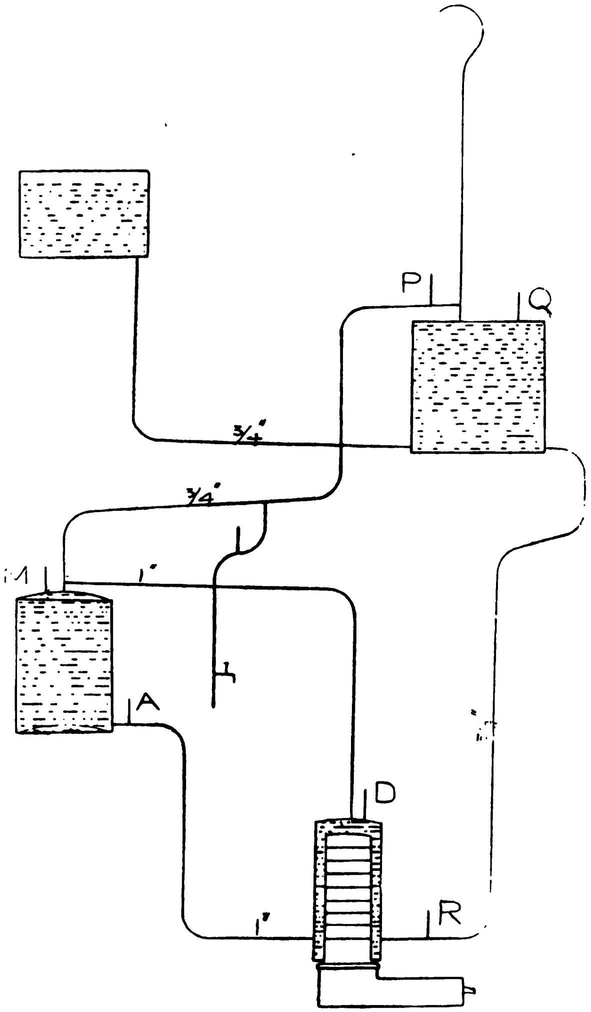


FIG. 41 (EXPERIMENT NO. 4).—DRAWING SHOWING ARRANGEMENT OF APPARATUS.

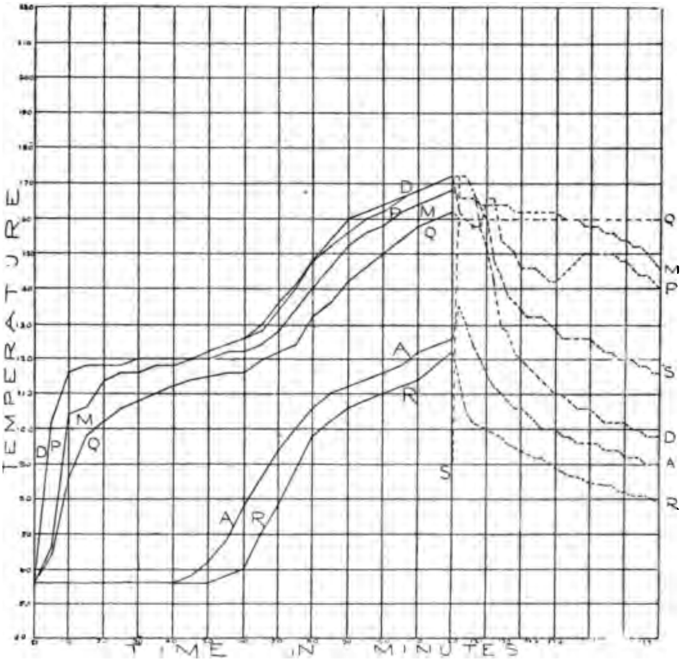


FIG. 41A (EXPERIMENT NO. 4).—DIAGRAM SHOWING RESULTS PLOTTED.

"this is one of the best methods of connecting a cylinder and tank system," *so far as the heating of the water is concerned.*

However, there is another equally important question to be considered, which is "Can the water be drawn off when it is heated?" On looking at the curves it will be seen at a glance that this system will not yield the maximum quantity of hot water.

The results shown by Fig. 41A are perhaps the most interesting and instructive of the whole series, and convey many useful lessons regarding the heating and also the draw-off periods. For instance, if we study the heating period we are struck with the fact that both the cylinder and the tank heated uniformly. This did not happen by chance, and for the reason we have not far to seek.

When considering hot water circulation one is apt to think of hot water as a rising body always endeavouring to gain the highest point. This is a wrong view to take. It has already been pointed out that hot water does not rise of itself, but only ascends when it is displaced by colder water. When thinking of hot water systems we should always look on the cold-return-water as a falling body. Viewing the system (Fig. 41) from this standpoint, it will be seen that the water in the tank and cylinder, being cold (heavier) bodies, free to fall without *obstructing* one another, poised up the heated water from the boiler which, as a matter of course, replaced the cold water in the cylinder and tank.

The results obtained during the draw-off simply confirm others previously obtained by experiments on simpler systems. The results are similar in many respects to those obtained from Experiment 22, Fig. 17. The major quantity of water flowed by way of the boiler, and having reached the boiler it had two avenues by which to travel on its passage to the tap, *i.e.*, the flow and the return pipe. It will be seen by the curves that during this period cold water was flowing through both these pipes, the flow pipe delivering cold water at the branch over the top of the hotter water contained in the cylinder.

Were it not for the indications of the thermometers the system might be looked upon as fairly successful, seeing that the average temperature of the first twenty gallons of water drawn off was 142 degrees. However, the plotted results show that the system proved itself to be very defective during the draw-off period, inasmuch as it failed to deliver the hot water unmixed with colder water or at its own maximum temperature.

The defects were that colder water than that in the cylinder found its way up the flow pipe, and was delivered at the tap before the supply of hot water in the cylinder was exhausted; and also that only a limited quantity of the water in the tank was drawn off. This result very forcibly illustrates the evil effect that may attend the connecting of a branch-pipe for draw-off purposes to a loop pipe, which has been dwelt upon at some length when dealing with some of the other systems.

The defect during the draw-off period might be minimised by connecting the primary flow somewhere down the side of the cylinder, or by connecting the secondary return to the bottom of the cylinder, preferably the latter—either of which may be responsible for introducing other defects that it is as well to avoid.

Fig. 42 shows another apparatus on the cylinder and tank principle. The secondary flow entered the tank four inches from the top, and the secondary return entered the side of the cylinder, the cold supply being connected to the bottom of the tank. A coil boiler, bent out of 30 feet of hydraulic tube, fitted into a slow combustion stove and heated by a coke fire, was employed in this and a number of other experiments, but this boiler was found not to be so convenient for Technical School experimental work as a gas-heated boiler. The fact that the secondary return entered the cylinder considerably affected the speedy heating of the water in the cylinder (see curves A), but the advantage gained during the draw-off somewhat counterbalanced this.

While the results shown by Fig. 42A are the best obtained from any system on the cylinder and tank principle, it is well to remember that it embodies defects which have already been dealt with, and lack of space forbids repetition. That the systems shown by Figs. 39, 40, 41 and 42 all embody defects is proved by the accompanying diagrams, and whilst unnecessary weight need not be attached to these results, seeing the systems were only miniature, yet the principles involved are equally applicable in practice.

## CONCLUSION.

It is just possible that some practical readers may not have been able to follow the thread of these articles, for, after all, diagrams and curves are not much in the plumber's line. As the object of this work would not be served if the writer did not make himself plain to all interested readers, it might be well before closing to draw a few practical lessons based on the foregoing results that may be helpful to all such, as well as those who feel disposed to search deeper into the subject.

In the first place it must be clearly understood that the boiler is of primary importance, and on its efficiency and sufficiency the success of a system largely depends; and, moreover, that it is not the size of the boiler, but rather its heating capacity or exposed heating surface, which constitutes a good boiler. The ordinary kitchen boiler (especially that of the boot and bath type) leaves much to be desired, for it can hardly be claimed that it is constructed on economic lines. What is wanted is a boiler simple in construction with a large heating surface proportioned to its capacity.

Having secured a good boiler—kitchen, independent, or other—it is then the plumber's business to design the hot-water system according to the capabilities of the boiler, and the requirements of the house. The system to adopt will depend upon circumstances, whether simply a "cylinder system," a "secondary circulation system," or a "cylinder and tank system"; as will also the sizes of the various pipes, taps, &c. The nature of the water will also be an important consideration, as a boiler and arrangement of pipes adapted for one quality of water might be wholly unsuitable for another.

The first pipe to consider is perhaps the primary return-pipe. The treatment of this pipe permits of no dispute, and it is recognised by all that this pipe must be taken out of the bottom —and, it may be added, the extreme bottom—of the cylinder or tank, and returned into the boiler at a low level.

The next is the primary flow, the treatment of which, unlike the return, does leave room for difference in opinion. However, it is hoped that the results of this series of experiments will help to remove doubt as to the best method of connecting it. The proposal that it should be connected to the extreme top of the cylinder, even though supported by experimental fact, requires perhaps some fuller explanation.

Let us take for example a system fitted with a 30-gallon cylinder, which contains 300 lbs. of water, supposing the water to be at 50 degrees and that we require 10 gallons at, say, 140 degrees. To obtain this the water must be raised through 90 degrees ($50 + 90 = 140$).

To raise 10 gallons—100 lbs.—of water 90 degrees requires 9,000 heat units ($100 \times 90 = 9,000$).

Let the heating capacity of the boiler be taken as 500 heat units per minute—$\frac{9000}{500} = 18$. Thus the boiler would be capable of raising 10 gallons of water through 90 degrees in 18 minutes; or in other words, 9,000 heat units would be transmitted to the water in the cylinder in 18 minutes. For the sake of argument let it be supposed that the rate of flow from the boiler is 10 gallons in this time.

If the system be connected as in Fig. 11 (Exp. 12)—the flow entering the bottom of the cylinder—the 9,000 heat units will be distributed through 30 gallons, which would mean a temperature of 80 degrees; whereas if the system be connected as in Fig. 10 (Exp. 7)—the flow entering the extreme top of the cylinder—the 9,000 heat units will be distributed through only 10 gallons, which means that the 10 gallons at the top of the cylinder would be at a temperature of 140 degrees, while the remaining 20 gallons at the bottom of the cylinder would be at the original temperature, 50 degrees.

Let it be assumed that the branch is taken off the top of the cylinder, and that the particles of water pass out of the cylinder in their order. In the former case the first 10 gallons would

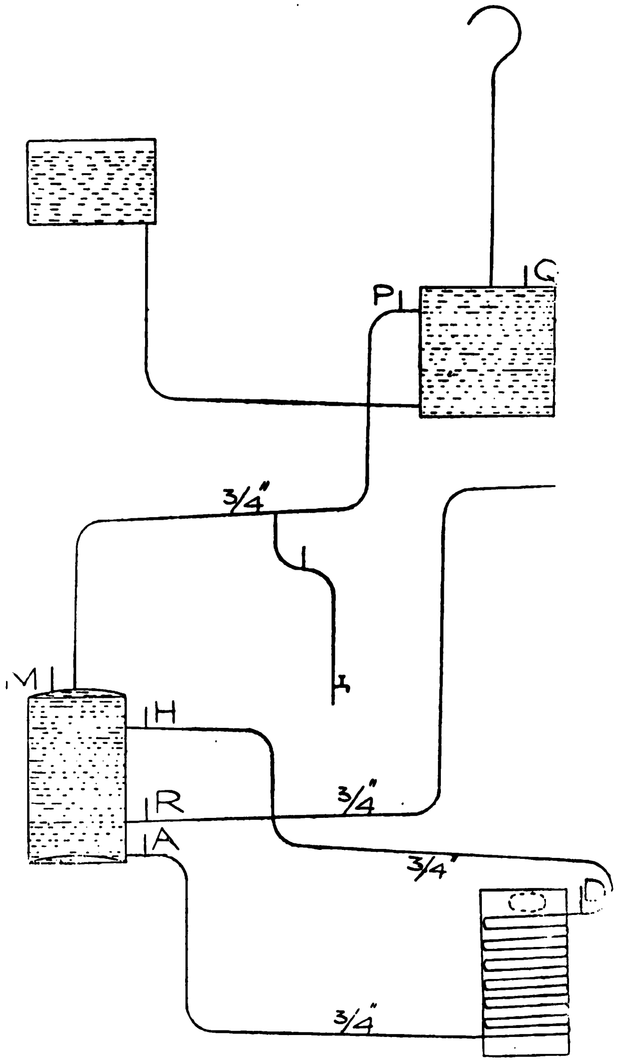


FIG. 42 (EXPERIMENT NO. 4).—DRAWING SHOWING ARRANGEMENT OF APPARATUS.

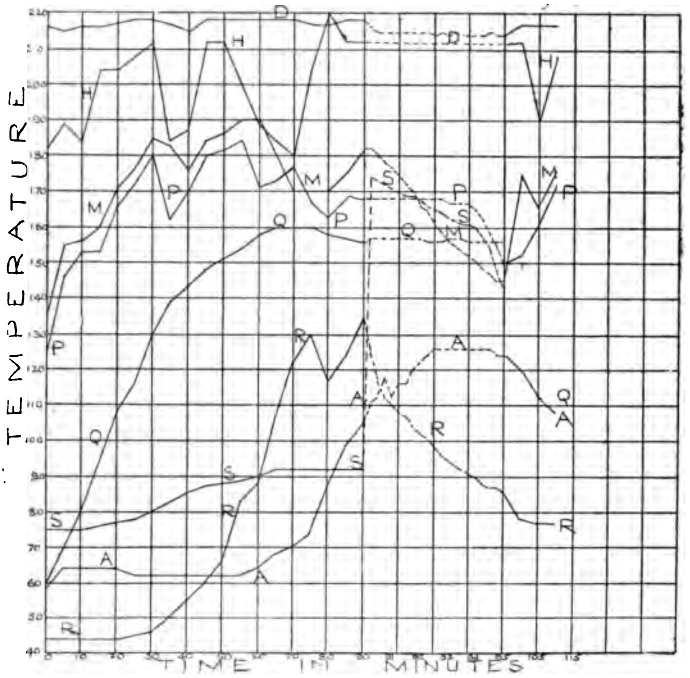


FIG. 42A (EXPERIMENT No. 4).—DIAGRAM SHOWING RESULTS PLOTTED.

contain 3,000 of the heat units transmitted from the boiler, while in the latter the first 10 gallons—*in theory*—contain all the 9,000 heat units. In practice this would be assuming too much; at the same time it tends to convey the reason why the flow should not be connected to the bottom of the storage cylinder or tank, and points to the conclusion that it is not sufficient to have the heat units contained in the cylinder or tank, but that the hot water must be concentrated and placed so that the maximum quantity may be delivered at the tap during the period of draw-off.

In the above assumed systems the same number of heat units was transmitted from the boiler to the water in the cylinder in each case; but in the one case the hot water was conveyed to the top of the cylinder and placed in position ready to deliver itself when the tap was opened, whereas in the other case the hot water passing through a colder volume gets chilled and diluted. This view has all through the present research been supported by the results of experiments which place beyond doubt the fact that the method of connecting the flow to the bottom is a wrong one, and that better results will be obtained if this pipe enters the cylinder at a higher level.

The further question is here raised, "How far up the cylinder should this pipe be carried?" If the same line of reasoning be followed we arrive at the conclusion that the extreme top is the proper position for the pipe to enter, and again this is supported by the results of numerous experiments. The writer is of opinion that this should be done, not alone in the case of the cylinder, but it is also the best treatment for the secondary flow entering the tank—in a cylinder and tank system—and it is also the best method of connecting a radiator.

This brings us to consider the shape of hot water storage vessels, and, if cylinders, whether they should be fixed vertically or horizontally. There can be little doubt in the mind of anyone who has closely followed these experiments as to the method of fixing a cylinder that is calculated to give the best results. If a cylinder be fixed in a horizontal position the hot water is distributed over a large area, and while this will not affect the mean temperature of the whole volume, yet the hot water is not stored in such a position as to ensure the hottest water being drawn off. On the other hand, if the cylinder be fixed vertically and the flow connected to the top, the hot water is stored more compactly as it were, and as the water at the top of the cylinder is the first to flow to the tap, this is an important consideration.

The treatment of the cold supply, has been fully explained when dealing with Experiments 19, 20, 22 and 23, which show why this pipe should be connected to the bottom of the cylinder, and set forth the advantages to be gained by turning it in a downward direction in order that the cold currents may be broken up and that the water may be made to rise in the form of a sheet instead of a jet. It is scarcely necessary to add that branch pipes should not be taken off the circulating pipes.

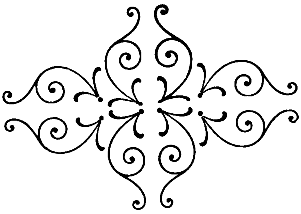
If a system be fitted up on these lines the water will circulate from the cylinder to the boiler and back to the cylinder in its order, the hottest water always being found at the top of the cylinder. When a tap is opened the cold water coming in at the bottom rises in the form of a sheet or plate, displacing the hot water, which issues from the tap in its order, no mixing taking place during either the heating or draw-off periods.

In the case of a secondary circulation system the same remarks apply. Avoid mixing hot and cold water in hot water systems, return cold water into a cold strata, and as the secondary circulating pipe is not used nor intended for warming the building, all that is wanted is a movement in the water to prevent stagnation. Therefore the secondary return need only be a bye-pass—to use a familiar term. It would be well if the cylinder and tank system—where such becomes necessary—could be constructed on the above lines. The mixing of the water during the heating, and drawing off mixed water while a store of hotter water remains untapped, are points to guard against.

The best results will be obtained when the circulation of the water is based on the balance principle, and when a draw-off tap is open the water is displaced in an upward direction. Any attempt to draw hot water downwards must be attended with indifferent results.

There is no doubt but that other Technical Schools will adopt this method of instructing the students in heating and hot water supply. Blackboard instruction is very good in the absence of something better, but there can be little doubt that a practical experiment conducted by the students will be more instructive, and convey a knowledge of the subject much more effectively than it is possible to do with chalk and blackboard. The writer would strongly recommend teachers of plumbing classes to endeavour to have some such water heating apparatus as that found in the Municipal Technical Institute, Belfast, in order to supplement the theoretical instruction given on this important subject.

While these experiments are to an extent exhaustive, yet it cannot be claimed that they are complete, for only the very fringe of the subject has been touched upon, much more remaining to be done.



# THE HEATING OF A SMALL VILLA.

A COMFORTABLE home is said to be the direct road to happiness, and to this may be added that if the home is to be thoroughly comfortable there must be warmth, in addition to abundance of light and fresh air.

The heating and ventilating of dwelling-houses, as well as public buildings, is a question which, during recent years, has received—and rightly so—a great amount of study, having attracted considerable attention from the medical profession as well as heating and ventilating engineers. Many are the devices which have been introduced and methods adopted in order that health and comfort may be brought within reach of the occupants.

As might be expected, considerable difference of opinion surrounds this question. One man pins his faith to fires as the best means of heating and ventilating rooms; another advocates hot air; while some, again, prefer hot water; each advancing arguments in favour of what he considers the best method. Although this article is intended to deal with hot-water heating systems, still the writer must confess a weakness for a good fire, and ofttimes his mind wanders back to the golden days of boyhood, and in fancy recalls the big turf fire, with the stump of an ancient oak tree for a back, piled high upon the hearth, emitting light and heat to the furthest corner of the room, many yards square, and making the old rafters look like polished ebony; enabling one "to read his book by chimney-nook" or, perchance, gaze into the starlit sky, which might easily be seen above the wide chimney as you sat beneath the old-fashioned "brace," with no modern draperies or inartistic ornaments to exclude fresh air and harbour disease germs. No, there we found heat, light and perfect ventilation combined to impart health and comfort. But alas! the current of events has borne many of us away from the pure, free, rural life, and circumstances have decreed that we must live and move in an atmosphere where such primitive, though none the less perfect, methods of heating and ventilation are impossible.

With the advance of science the complexion of many things has changed. The squire's log-fire has given place to the American radiator or the gas-stove, and the old-time brace, which fulfilled the twofold purpose of a smoke stack and ventilating shaft, finds a substitute in the close range, the mica flap doing duty for an outlet ventilator.

Notwithstanding the improvements which have been made in other respects in the houses of the working and middle classes during recent years, very little has yet been done to artificially heat and properly ventilate the homes of the masses, and only the mansions of the moneyed man have received attention at the hands of the plumber and heating engineer. The heating of a mansion very seldom presents any real difficulty, his lordship being possessed of what Napoleon called "the sinews of war," and, being usually generous where his own comfort is concerned, is able to call into existence by his magic word an arrangement of pipes heated by an independent boiler, even though later on he may be called upon to dance to a tune on the pipes of the plumber. But to successfully instal a simple, effective and economic heating system, suitable to the homes of the masses who are unable to pay the piper a ransom for his tune, is a more difficult task, but not an impossible one.

Anyone who takes the trouble to study the kitchen-range as met with in the ordinary house must be struck with the fact that there is a great waste of heat, which could be utilised if turned into proper channels, and be of great service in warming the other living rooms of the house, thereby giving the householder a better return for his coal bill.

In order to place before his readers what can be accomplished in this direction, the writer has fitted up an installation of heating from the kitchen-range in a small five-roomed cottage, and from close observations of the working of the system, his conviction that it is possible to successfully heat a dwelling-house from the kitchen-range has been fully confirmed, and it is hoped the result of experiments conducted will establish this fact.

The plans and section of the cottage are shown by Figs. 1, 2, and 3. Parlour, kitchen, scullery, wash-house, &c., on ground floor; study, two bedrooms, and bathroom on first floor. The living portions of the house contain 8,000 cubic feet. The house is dependent for its water supply on a pump drawing water from a deep well, and large storage for rainwater is also provided. The well water might be called, from a plumber's point of view, a "harmless" water, not precipitating a lime deposit when heated or boiled, which simplified matters when deciding on a boiler and arrangement of pipes suitable to the requirements.

The boiler employed is shown by Fig. 4. It is set behind a 42 in. slow combustion range, having a 10 in. fire. The setting of the boiler is shown by Fig. 5. It will be seen that the boiler has

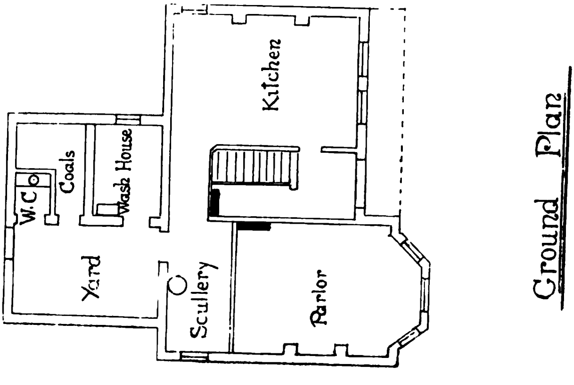


FIG. 1.

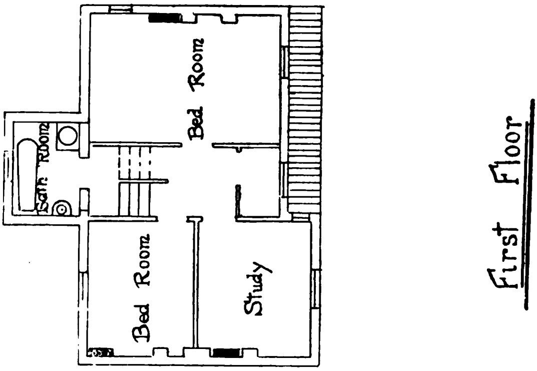


FIG. 2.

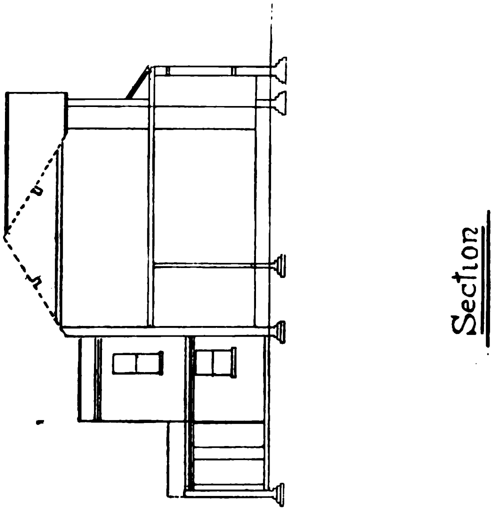


FIG. 3.

not been fitted with a handhole door. This may be looked upon—and in a great many cases *would* be—as a great objection, but the writer's experience has been that the handhole doors of boilers in Belfast are seldom if ever used. This is owing to the nature of the water with which Belfast and district is supplied, chipping boilers being a thing unknown in the locality. The boiler is provided with a sludge pipe, which, when used frequently, prevents any sediment accumulating in the boiler.

The rooms are heated by radiators P, H, S, $B^1$ and $B^2$ (the positions are shown on plan Figs. 1 and 2), connected on the one-pipe system, the main circulating pipe being 1 in. (galvanized iron), 100 ft. long; the branches to the radiators are ¾ in. The wisdom of using such small pipes to heat five radiators will be questioned by some, but in practice these particular pipes work well and fully meet the requirements.

Fig. 6 shows the arrangement of pipes, radiators and boiler; also the cylinder, towel-rail and branches in connection with the domestic supply. The flow and return to the cylinder are ¾ in., 20 ft. long (each). In all about 150 ft. of circulating pipe are employed. The levels of the different sections are figured on the drawing, Fig. 6, which should be carefully studied. These show that the return dips 4 in. below the boiler in order to cross below a door. It will be seen by the drawing that the return from the cylinder is connected to the return from the radiators 9 ft. before it enters the boiler; otherwise the domestic supply has no connection with the heating section. The domestic supply circulation is controlled by a sluice-valve on the primary return, and the heating section is controlled by another valve before it is joined by the return from the cylinder, so that each section can be used at will. Each radiator is fitted with a valve, as is also the towel-rail in the bathroom. In all there are eight controlling valves on the system.

The cylinder and the boiler are made of copper, and the towel-rail of 1 in. iron pipe. The positions of the fittings as well as the connections and branches are best explained by Fig. 6. The radiators in the parlour and bedroom No. 1 are eight loop, 2 ft. 6 in. high, and have a catalogued heating surface of 26 square feet. Those in the study, bedroom No. 2 and hall are six loop, 2 ft. high, and are catalogued as having a heating surface of 15 square feet.

Air flues are carried up alongside the chimney flues for the purpose of up-take ventilation, and each room is connected to these flues by an outlet ventilator fixed close to the ceiling, having an area of 30 sq. in. Air is admitted to the rooms by fixing a slip of wood below the bottom sashes of the window—Bird's ventilators—which method is too well known to need any explanation.

The house is in an exposed position, having a north-west aspect, and at the time these experiments were conducted

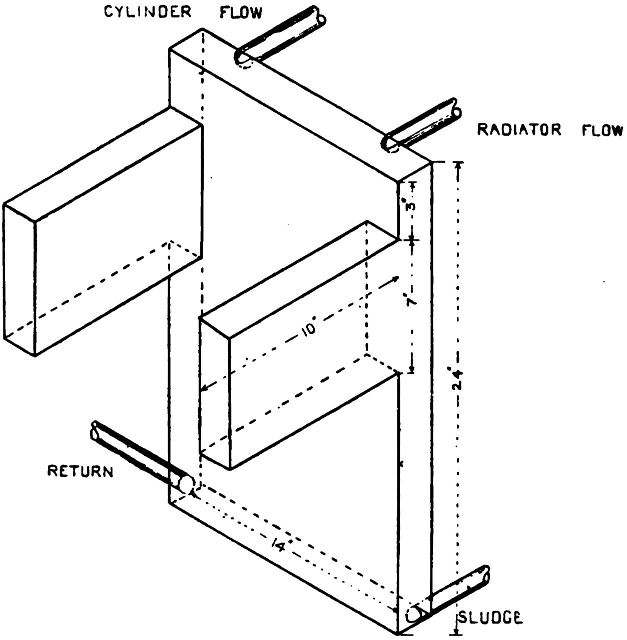


Fig. 4.—View of Boiler.

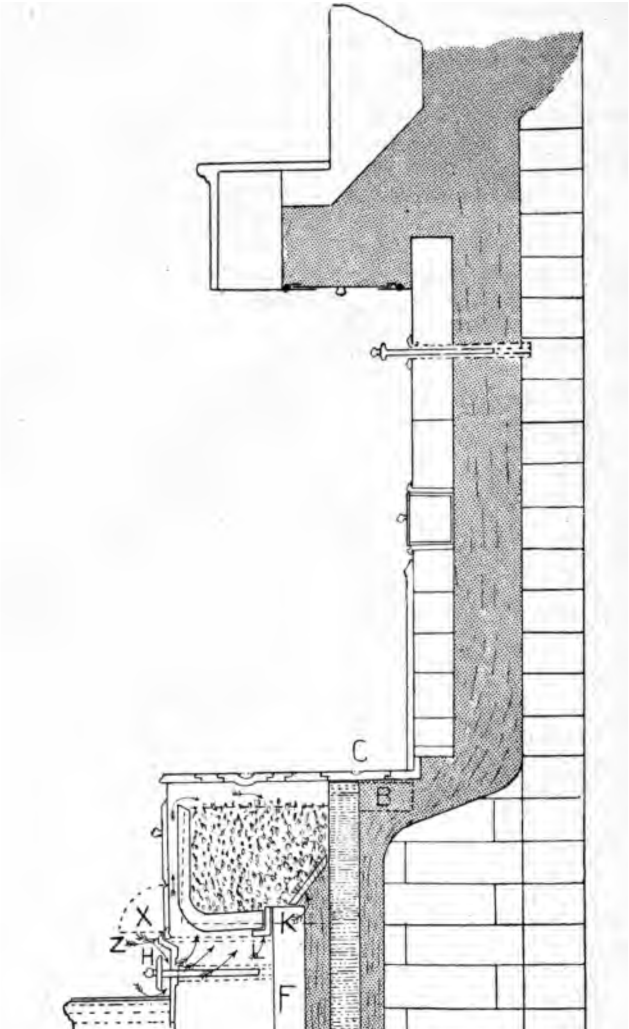


FIG. 5.—SECTION THROUGH RANGE.

had only been recently built. The experiments were conducted on 26th and 27th December, 1904, from 6 a.m. on the morning of the 26th to 9 a.m. on the morning of the 27th (27 hours). The system was fitted with thermometers, much in the same manner as in the experiments conducted at the Technical Institute. The weather unfortunately was not ideal for a severe test of a heating system. One is apt to associate Father Christmas with frost and snow, and when children we were wont to picture him in a fleecy mantle with an icicle beard. But no such venerable gentleman presented himself in the year 1904, for the morning of the 26th December was ushered in with a fog hanging over it like a curtain, and not a movement in the air, while the thermometer stood at 40 degs.

The experiment, to be precise, was one of the nature of a record of the routine of the house, including, amongst other points, the coal consumption, ash produced, time of lighting fire, time of retiring, temperature of air, inside and outside, the temperature of the water at different points, and the quantity of water drawn off. The general routine of the house was strictly adhered to in order that the result might represent the normal state of affairs.

On December 25th, at 9 p.m., the fire was banked with a shovelful of slack, as was the usual custom; this being done for the twofold purpose of keeping the rooms moderately warm all night, and also keeping up the temperature of the water so that it might be more easily heated the next morning. But on this particular morning (26th) it was found to have gone out, so the experiment commenced with having to light the fire, and starting, as it were, from "scratch." The flues were thoroughly cleaned, and the wood and coals—the latter having been previously weighed—were placed in the fire-box ready for the match to be applied. The temperature recorded by the thermometer fixed on the system, and those placed in the various rooms and the one outside—fifteen in all—was then noted, the time being 6 a.m.

The fire was lighted and the boiler damper drawn full (5 in.). The oven and the sham dampers were also drawn a little until the fire was properly lighted. When the fire was well started the two side dampers were shut, the boiler damper remaining drawn full for the first hour. At 7 a.m. the readings of the thermometers were again noted, also at 8 a.m., and every hour until 10 p.m., as tabulated below. At 7 a.m. the boiler damper was closed to half-full (2½ in.), and at 7.30 sufficient hot water was drawn off to give a plunge bath. During the first period of the draw-off the water was issuing from the tap at 145 degs., and at the end of the draw-off the temperature was 135 degs.

At 8 o'clock the boiler damper was closed further to 2 in., and radiator $B^1$ turned off, while radiator $B^2$ was almost turned off, the valve being left slightly open to show that it is possible

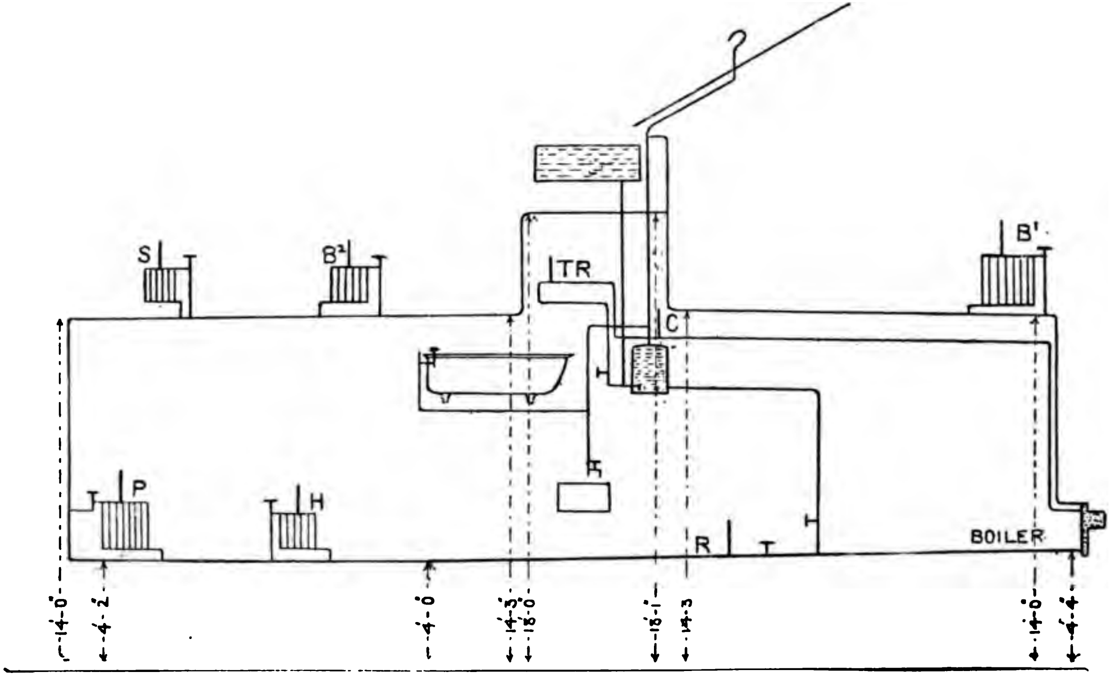


FIG. 6.—PLUMBING AND HEATING ARRANGEMENTS.

in a system like this to keep a radiator at any desired temperature.

At 8.30 a.m. 10 gals. of water were drawn off, the mean temperature of which was 135 degs. At this stage the valve on the cylinder return was reduced to half-fullway, and at 10 o'clock it was found that the water was returning from the cylinder quite hot, which went to show that the entire water in the cylinder was heated. At 9 o'clock the boiler damper was reduced to 1 in., and remained so until 4 p.m. The range was used for the ordinary household cooking, and small quantities of water were drawn off from time to time, as is usual in a house.

There was no great demand on the fire from 9 o'clock till 12 noon, when the oven damper was drawn full (5 in.), the oven being used from 12 o'clock till 2.30 p.m. for baking purposes. During the period the oven damper remained open the temperature of the water at the various points was well maintained, as will be seen when studying the plotted results. The use of the oven flue had little or no effect on the heating of the water.

It was found at 9.30 a.m. that 20 lbs. of coal (one bucketful) had been used. Another bucketful (20 lbs.), half coal and half slack, was weighed, which quantity lasted until 2 p.m., when another 20 lbs. of coal and slack was weighed, this lasting till 10 p.m.

Four gallons of water were drawn off at 2.30 p.m., and at 4 p.m. radiators $B^1$ and $B^2$ were turned on full in order to heat the bedrooms. The boiler damper was drawn to 1½ in. from 4 to 5 o'clock. After the radiators were turned on there was a slight fall in temperature recorded by some of the thermometers, but this was only of short duration, for at 4.30 the thermometer on the return, which had fallen to 113 degs., commenced to rise again.

In the afternoon 5 gals. of water were drawn off. This was obtained at a temperature of 125 degs., which, by the way, is about the proper temperature for washing-up purposes. As no more water was required the valve on the cylinder return, which had been half open from 8.30 a.m., was turned off at 7 p.m. From this period on only the radiators were being heated. From 7 to 10 p.m. the fire was very low, but it will be seen on referring to the results that the temperature of the water in the system was fairly high, and that the temperature of the air in the rooms was comfortable.

The fire was banked with 6 lbs. slack at 10 p.m.; and at 6 a.m. next morning it was found that there was a fairly good fire, which is the usual thing when the fire is properly slacked at night.

DATE OF EXPERIMENT, 26TH DECEMBER, 1904.

| | a.m. | | | | | | | p.m. | |
|---|---|---|---|---|---|---|---|---|---|
| Time in hours | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 |
| Thermometer P | 74 | 83 | 115 | 158 | 167 | 167 | 167 | 172 | 164 |
| ,, H | 74 | 74 | 100 | 140 | 149 | 149 | 149 | 149 | 149 |
| ,, S | 78 | 100 | 120 | 170 | 175 | 175 | 170 | 180 | 170 |
| ,, $B_1$ | 82 | 140 | 149 | 104 | 95 | 81 | 81 | 77 | 77 |
| ,, $B_2$ | 77 | 113 | 149 | 108 | 104 | 104 | 104 | 104 | 104 |
| ,, R | 68 | 77 | 99 | 131 | 140 | 140 | 140 | 140 | 136 |
| ,, C | 77 | 149 | 140 | 180 | 149 | 169 | 165 | 167 | 167 |
| ,, TR | 75 | 140 | 125 | 160 | 145 | 160 | 155 | 165 | 160 |

| | p.m. | | | | | | | | a.m. |
|---|---|---|---|---|---|---|---|---|---|
| Time in hours | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 6 |
| Thermometer P | 167 | 162 | 140 | 140 | 140 | 140 | 131 | 131 | 77 |
| ,, H | 149 | 145 | 131 | 131 | 131 | 128 | 122 | 122 | 77 |
| ,, S | 175 | 170 | 150 | 145 | 145 | 145 | 140 | 140 | 82 |
| ,, $B^1$ | 77 | 77 | 172 | 162 | 164 | 167 | 158 | 162 | 95 |
| ,, $B^2$ | 104 | 104 | 158 | 154 | 158 | 158 | 149 | 154 | 82 |
| ,, R | 136 | 136 | 113-131 | 122 | 122 | 118 | 115 | 113 | 77 |
| ,, C | 172 | 169 | 140 | 149 | 149 | 113 | 95 | 86 | 72 |
| ,, TR | 160 | 160 | 160 | 150 | 145 | 145 | 100 | 90 | 70 |

| | a.m. | | | | | | | p.m. | |
|---|---|---|---|---|---|---|---|---|---|
| Time in hours | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 |
| Temperature of Air— | | | | | | | | | |
| Outside | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 41 | 41 |
| Parlour | 55 | 50 | 48 | 58 | 62 | 63 | 63 | 64 | 64 |
| Hall | 56 | 56 | 58 | 61 | 63 | 63 | 64 | 65 | 64 |
| Study | 55 | 55 | 55 | 57 | 60 | 62 | 62 | 64 | 64 |
| Bedroom No. 1 | 59 | 60 | 61 | 58 | 58 | 58 | 58 | 58 | 58 |
| Bedroom No. 2 | 57 | 58 | 61 | 59 | 57 | 58 | 58 | 60 | 60 |
| Kitchen | 59 | 59 | 62 | 67 | 65 | 65 | 65 | 67 | 67 |

| | p.m. | | | | | | | | a.m. |
|---|---|---|---|---|---|---|---|---|---|
| Time in hours | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 6 |
| Temperature of Air— | | | | | | | | | |
| Outside | 40 | 40 | 41 | 42 | 42 | 41 | 40 | 40 | 39 |
| Parlour | 65 | 64 | 65 | 64 | 64 | 64 | 64 | 64 | 56 |
| Hall | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 56 |
| Study | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 55 |
| Bedroom No. 1 | 58 | 58 | 62 | 63 | 63 | 63 | 63 | 63 | 61 |
| Bedroom No. 2 | 60 | 60 | 62 | 63 | 64 | 63 | 63 | 63 | 59 |
| Kitchen | 66 | 66 | 67 | 66 | 67 | 67 | 67 | 67 | 59 |

All that is required from the average kitchen-range in addition to the ordinary household cooking is the heating of water for domestic purposes, but in the case of the range we are now dealing with the heating of the water for domestic use is only a very small part of the work done by this boiler; for the surplus heat is utilised and turned into channels for distribution, by means of radiators, in other parts of the house.

Let us now go back to 6 o'clock on the morning of the 26th, and glance at the readings of the thermometers, which were as follows:—Bedroom No. 1, 59 degs.; Bedroom No. 2, 57 degs.; Study, 55 degs.; Parlour, 55 degs.; Hall, 56 degs.; Kitchen, 59 degs. These were the temperatures of the air inside while the thermometer outside registered 42 degrees. If we turn to the tabulated results we see that by 7 a.m. the temperature of the air in rooms $B^1$ and $B^2$ had gone up 1 degree, and at 8 o'clock the thermometers registered 61 degrees in both rooms, being a rise of 2 degrees and 4 degrees respectively.

The house was a new one, and as no fires save the kitchen range had been used for six weeks previous to the date of these experiments, to what was the rise of temperature due? The answer is, to the surplus heat of the kitchen range, which was being used for heating these rooms. On referring to the readings of the thermometers which were fixed on the radiators, we see that $B^1$ recorded a temperature of 82 degrees before the fire was lighted, at 7 o'clock 140 degrees, and at 8 o'clock—two hours after the fire was lighted—149 degrees; while at the same time the readings of the thermometer on the radiator in bedroom No. 2 were 77 degs., 115 degs. and 149 degs. respectively; so that the heated water from the kitchen boiler was flowing through these radiators, which in turn were radiating heat and warming the air in the various rooms of the house. Nor had the heating power of the water been exhausted at this point, for we see by the readings of the thermometers that it passed on to the radiator in the study, and thence to those in parlour and hall, distributing through each a considerable amount of heat.

To treat in detail the various readings of the fifteen thermometers, taken every hour, would be wearisome to both reader and writer alike. It is therefore advisable to leave these readings in tabulated form for the reader to study for himself, and to proceed with the more general treatment of the subject. Before doing so, however, it is well to note that although the boiler dispensed heat liberally through the radiators, the cylinder, or domestic supply, did not suffer, for the readings of the thermometers on cylinder and towel-rail show that an ample supply of hot water had reached these points. Readings of thermometer on cylinder: 6 a.m., 77 degs.; 7 a.m., 149 degs.; 8 a.m., 140 degs. Thermometer on towel-rail: 6 a.m., 75 degs.; 7 a.m., 140 degs.; 8 a.m., 125 degs. In addition to this we have to take into account the fact that sufficient hot water for a bath had been drawn off at 7.30 a.m. (one hour and a half after the fire was lighted). Therefore it will be seen that the system was not only yielding abundance of hot water for domestic use, but it was also heating the rooms.

These results were obtained under the following conditions. We will start with Bedroom No. 1. On the night of the 25th, the window looking N.W. was open 9 in. at the top.

The west window having a slip of wood below the bottom sash was also acting as an inlet ventilator. The outlet, 30 in. in area, close to the ceiling—already described—and an open chimney, were the means of outlet ventilation. At 6 a.m. on the morning of the 26th the upper sash of the N.W. window was shut, the two windows acting as Bird's ventilators. On the range being lighted the radiators quickly heated up, as did also the air in the room, which is most desirable when dressing in the morning, especially where there are young people or children.

At 8 a.m. the occupants had left the room, the radiators were turned off, and the windows opened full top and bottom. The temperature of the water is shown by Fig. 7, and the change of temperature of the air is shown by the curves,

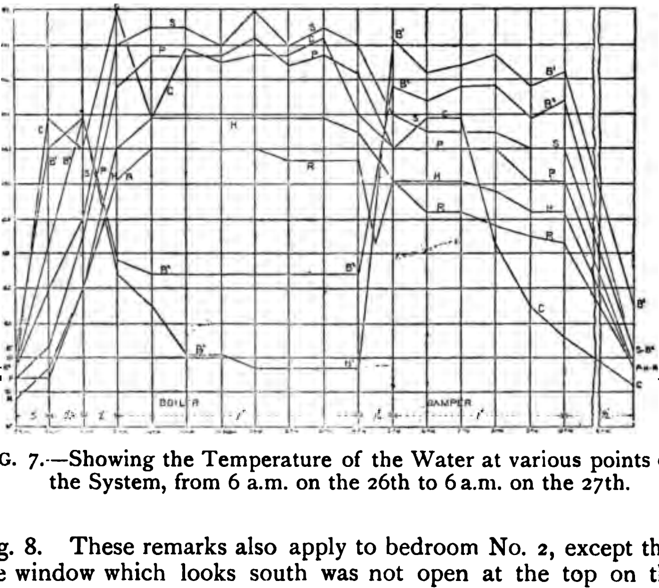


FIG. 7.—Showing the Temperature of the Water at various points on the System, from 6 a.m. on the 26th to 6 a.m. on the 27th.

Fig. 8. These remarks also apply to bedroom No. 2, except that the window which looks south was not open at the top on the night of the 25th, but was simply acting as Bird's ventilator, the same as all the windows in the house, every window being fitted with a slip of wood below the bottom sash. These rooms may be left till 4 p.m.

In the case of the study, we see that the temperature of the radiator did not rise so quickly as $B^1$ and $B^2$, nor did that of the air so quickly as that in the bedrooms. This was due to two causes—(*a*) this room having a N.W. aspect was more difficult to heat than one looking south; and (*b*) it was dependent on the radiator alone for heat, whilst rooms $B^1$ and $B^2$ had a considerable length of main circulating pipe passing through them. However, notwithstanding this, the temperature in the study at 10 o'clock was 60 degrees, and, later on, it went up to 64 degrees.

The windows in the parlour were thrown open from 6 a.m. to 8 a.m. to thoroughly air-flush the room, and from the diagram, Fig. 8, it will be seen that during this period the temperature was very low. The windows were shut at 8 a.m. when the temperature was 48 degrees; at 9 a.m.—an hour later—58 degrees were registered, being a rise of 10 degs. in one hour. And yet the radiator which heated this room was 70 feet from, and on a level with, the boiler. From this period throughout the entire day the air in the parlour was at a very agreeable temperature (see tabulated and plotted results); and not alone was the temperature agreeable, but the ventilation also was good, the three sashes acting as Bird's ventilators.

The hall next claims attention. It will be seen by the curves, Fig. 8, that the radiator in the hall received a wonderful amount of heat, although it was the most remote from the boiler and was depending on the return water from the other radiators for its heat. Notwithstanding these drawbacks, it was found capable of keeping the air in the hall and staircase at a normal temperature.

Heating without adequate ventilation is always oppressive; in all cases the one should be accompanied by the other. It may be taken that during these experiments each window acted as an inlet ventilator—unless otherwise stated—and that the outlet ventilators were continually open; in fact no means has been provided for closing them. The uptake shaft being simply a hollow chimney-breast surmounted by a chimney-pot, presents the appearance of a chimney-flue. It will thus be seen that there has been practically no outlay in providing what has proved to be a very effective means of ventilation. Whether this means of heating and ventilation is applicable, or would prove efficient on a larger scale, the author is not prepared to say; but in the case under study it has proved effective in securing a comfortable, wholesome atmosphere without any discomfort from draughts.

We may now glance at the coal consumption. Whilst the curve, Fig. 9, showing the coal consumption may not be strictly correct, the difficulty of showing coal consumption (which is a more or less piecemeal process) by a strictly accurate curve will readily be understood. The points on the curve enclosed by the circles are correct, and on the whole the curve is reliable enough for the present purpose. It will be seen that the coal consumption was greatest in the morning, much less being used in the evening.

These figures may be looked upon as either a high or low consumption, according to the view taken; but when the amount of work done is considered, it must be looked upon as

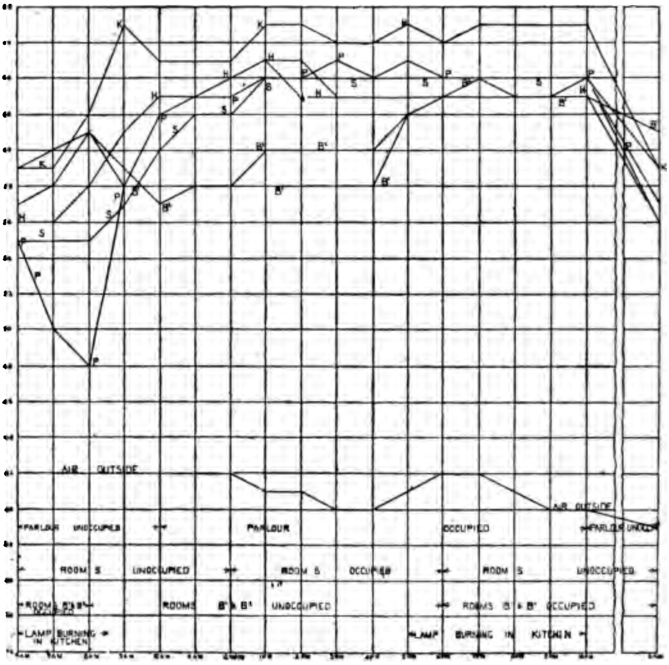


FIG. 8.—Showing the Temperature of the Air in the different rooms, also the Temperature outside, from 6 a.m. on the 26th to 6 a.m. on the 27th.

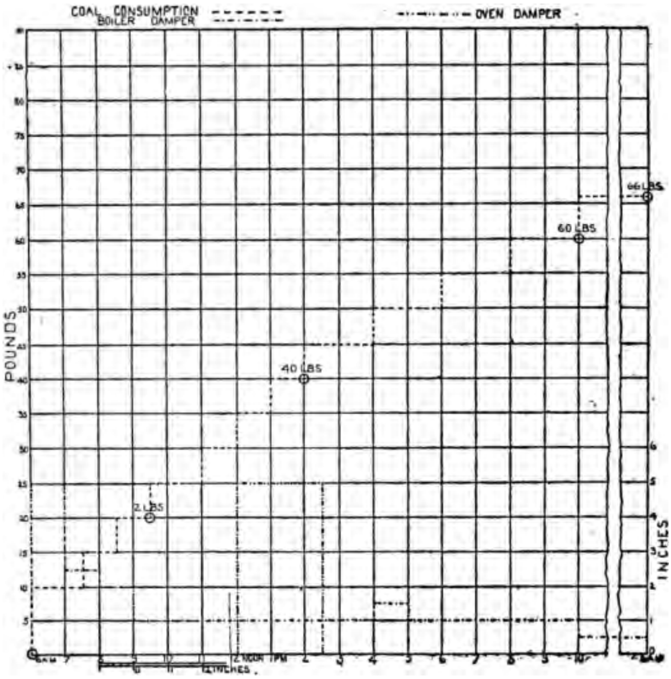


FIG 9.– Showing Coal Consumption and Dampers.

moderate, and well within the average consumption in the ordinary close range.

SUMMARY OF COAL CONSUMPTION.

| | | |
|---|---|---|
| 9.30 a.m. | 20 lbs. coal. | 0 lbs. slack. |
| 2.0 p.m. | 30 lb. „ | 10 lbs. „ |
| 10.0 „ | 40 lb. „ | 20 lbs. „ |
| 6.0 a.m. | 40 lb. „ | 26 lbs. „ |
| | Total | 66 lbs. |

It is essential that a heating system be under perfect contro in order that the temperature may be regulated at will, and this is a point on which the writer would lay special emphasis; for too often we meet with heating systems which, perhaps for the lack of a valve, are, to say the least of it, very inconvenient in warm weather. The results of these experiments show that the temperature of any particular room can be regulated. For example, if we turn to the diagrams, Figs. 7 and 8, and take, say, 4 p.m. in room B$^1$, and B$^2$, up to this time the radiators had been turned off and the windows full open; but when the windows were shut and the radiators turned on, the curves B$^1$ and B$^2$, Fig. 7, show that the temperature of the water in the radiators went up immediately, and the corresponding curves, Fig. 8, show that the temperature of the air in the rooms also went up as a natural consequence; while at the same time the air was continually changing owing to the means of ventilation provided.

On turning on the radiators, B$^1$ and B$^2$, the water at other points fell in temperature for a short time, as might be expected, but the temperature of the air in the other rooms underwent no appreciable change. At 6 p.m. the temperature of the bedrooms was found to be too high, and the windows were thrown open. Had it not been for the purpose of these experiments the radiators would have been shut off and the temperature kept down.

If the reader will turn to Fig. 9 he will see a dotted line representing the range "damped," from which it will be seen that during the greater part of the day the boiler damper was drawn only one inch. As the damper is an important factor, its position is given below in tabulated form:—

| TIME. | BOILER DAMPER. | OVEN DAMPER. | SHAM DAMPER. |
|---|---|---|---|
| 6 to 7 a.m. | 5 inches. | 1½ inches. | 1½ inches. |
| 7 to 8 „ | 2½ „ | Shut | Shut. |
| 8 to 9 „ | 2 „ | „ | „ |
| 9 to 12 „ | 1 „ | „ | „ |
| 12 to 2.30 p.m. | 1 „ | 5 inches. | „ |
| 2.30 to 4 p.m. | 1 „ | Shut | „ |
| 4 to 5 „ | 1½ „ | „ | „ |
| 5 to 10 „ | 1 „ | „ | „ |
| 10 to 6 „ | ½ „ | „ | „ |

From this table it will be seen that the firing was exceedingly moderate, yet, as will be seen from the other readings, there was ample heat in every part of the house; and as we arrive at 10 p.m. and balance the outlay against the work done, we find that 40 lbs. of coal and 20 lbs. of slack—60 lbs. in all, representing a cost of sixpence—had been used to heat 8,000 cubic feet, supplying hot water for domestic use, over and above the ordinary cooking, for a family of five.

At 10 p.m. 6 lbs. of slack were put on, and the boiler damper left open ½ inch with the range closed up. The following morning at 6 a.m. it was found that the fire kept alight all night, as usual, and when the fire-box had been raked out and the damper drawn, there was a very fair fire. The ash produced for the twenty-four hours was carefully collected and weighed, and when compared with the coal consumption, showed how complete was the combustion.

| | |
|---|---|
| Ashes in ash-box ... ... ... | 1 lb. |
| „ „ boiler-flue ... ... ... | 1 lb. |
| Total ... | 2 lbs. |
| Total coal consumption for 24 hours ... | 66 lbs. |
| „ ash produced „ „ ... | 2 lbs. |

On the morning of the 27th the experiment was continued for the purpose of showing how it is possible to control the heat at any particular point on the system.

From 6 a.m. to 8 a.m. the five radiators were on full, but the cylinder and towel-rail were not turned on, so only the heating section was circulating. At 8 a.m. the radiators in the study and the bedrooms were turned off, and the valve on the cylinder return opened at 8.30, and from 8.30 to 9 o'clock only the radiators in the parlour and the hall, and the cylinder and towel-rail were being heated. The results are tabulated below, and shown plotted on Fig. 10, from which it will be seen that a very high temperature was registered by the thermometers on some of the radiators. For instance, P at 8.30 registered 190 degrees. This in the writer's opinion is too high a temperature for radiators in living rooms; 160 to 170 degrees gives a much milder temperature.

It will be noticed that immediately the valve on the cylinder return was opened the temperature of the water in the cylinder went up very rapidly, as did also the temperature of the towel-rail. At 8.35—five minutes after the valve was opened—five gallons of water were drawn off at 160 degrees.

Whilst many very interesting points could be dwelt upon, there is one in particular that the writer would point out, namely, that when the valve on the cylinder return was opened, all the cold water from the cylinder did not travel direct to the boiler, but a portion found its way past R—the thermometer fixed on the heating section return—which indicates that the direction of the circulation in this section was reversed for the time being. This was a case of simple gravitation, the coldest (heaviest) particles of water finding the lowest point. This is a fact the plumber should ever keep in mind, for in hot water systems, such as the one under study, it invariably happens—indeed, it is the controlling factor of hot water circulation.

The above records show what can be accomplished from the kitchen-range, and viewed from a plumber's standpoint are most satisfactory. But let us look at them from another point of view. It is beyond dispute that in a cold, damp, uncertain climate like ours, warmth is one of the essential features of a comfortable

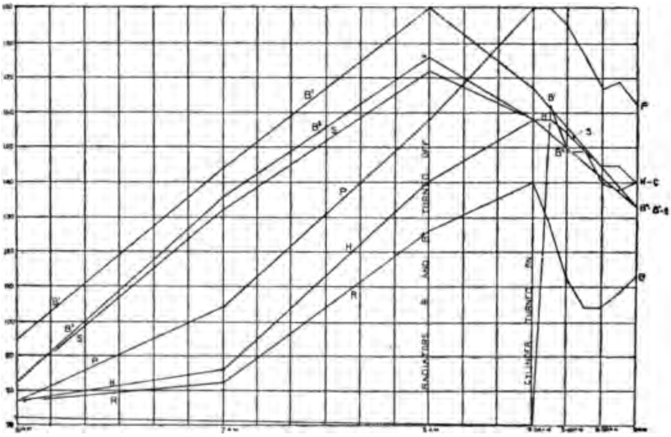


FIG. 10.—Showing Temperature of Water at various points on the System on the morning of the 27th.

home, and, as the author has tried to point out, the kitchen-range may more largely be employed to produce an equally warm temperature in every room in at least the smaller class of house. It is necessary—nay, imperative—that the various rooms in the house should be kept at a normal temperature, for nothing is more injurious to health than to leave a hot sitting-room, undress in a cold bedroom, and get under damp, unaired bedclothes. Yet, as a matter of fact, this is what most of our working and middle-class people do, because in nine cases out of ten it is impossible to have a fire in every room, which at present is generally supposed to be the only means available for heating.

Another feature of a great many city houses is that the rooms are so small that a fire either overheats the room or creates draughts. The air rushing in to supply oxygen necessary for the combustion of the fuel, and to supply the current induced by the draught of the chimney, causes a continuous stream of cold air to pass through the room in the direction of the fire, whilst it does not necessarily mean that the air in the room is being changed, and that the vitiated air is being replaced by fresh. When sitting in such a room one may feel their side next the fire quite hot, whilst the other side and feet are cold ; yet at the same time the air in the upper portions of the room may be hot and vitiated, because there is little or no change in the upper strata of air unless proper inlet and outlet ventilators are provided, which is seldom done. So, after all, open fires in small rooms are questionable luxuries.

What is required is heating and ventilation combined. If we leave our bedroom during one of our winter days with the windows open, in order that it may be properly air-flushed during the time it is unoccupied, we find on returning that the room is cold, and the bedclothes damp. To guard against this most people avoid opening the windows. They know that the air inside is drier and warmer than outside, but the question of pure air seldom presents itself to the ordinary housewife. We are inclined to blame people for not admitting more fresh air, but still they may, through ignorance or otherwise, have some grounds for this neglect. If warmth was carried into the homes cold and dampness would disappear, and people would throw open their windows and admit that health-giving fluid, "fresh air." Until this problem of combined heating and ventilation is solved and made applicable to the homes of the masses, there will always be a disinclination on the part of the people towards admitting fresh air into their houses.

We hear a great deal nowadays about the deterioration of the race. Yet how can it be otherwise? Take the case of a child in the ordinary working-man's home. It gets up in the morning from a warm bed and is suddenly put into cold clothes that have been left off the night before. Then at night it is again taken from a hot sitting-room, put into an unaired nightdress, to sleep in a cold, damp, unventilated room. This can have only one result, which we see everywhere in our streets—stunted young children, weak chests, diseased lungs, poor blood, before they reach the years of maturity. As the future well-being of our nation depends upon the children of to-day, and the health of generations yet to be on how the young are cared for now, surely no pains should be spared to exclude cold and dampness and expel bad air, with its disease-producing and life-destroying properties, and admit fresh air from which cold and dampness has been removed, thus making the home warm and comfortable.

Notwithstanding the many disadvantages of heating from the kitchen-range and all that can reasonably be said against such a system, the writer is of opinion that the kitchen range should be more extensively utilised for distributing heat to other parts of the house. No doubt there are a great many things to contend with, but if the members of the trade would only make some real effort in this direction, all difficulties would soon disappear, and hot-water heating systems from the kitchen boiler become part of the plumbing trade of the future.

DATE OF EXPERIMENT, 27th DEC., 1904, FROM 6 a.m TO 9 a.m.

| Time (a.m.) | ... | 6 | 7 | 8 | 8.30 | 8.35 | 8.40 | 8.45 | 8.50 | 8.55 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Parlour | P | 77 | 104 | 158 | 190 | 190 | 185 | 176 | 167 | 169 | 162 |
| Hall | H | 77 | 86 | 140 | 158 | 158 | 154 | 149 | 145 | 145 | 140 |
| Study | S | 82 | 132 | 172 | 158 | — | — | — | — | — | 133 |
| Bedroom | B1 | 95 | 144 | 190 | 167 | — | — | — | — | — | 133 |
| Bedroom | B2 | 82 | 136 | 176 | 158 | — | — | — | — | — | 132 |
| Return | R | 77 | 82 | 126 | 140 | 128 | 113 | 104 | 104 | 108 | 113 |
| Cylinder | C | 72 | — | — | 70 | 162 | 149 | 149 | 140 | 138 | 140 |
| Towel-rail | TR | 70 | — | — | 65 | 160 | 145 | 140 | 135 | 132 | 125 |